BOOK PRODUCTION WAR ECONOMY STANDARD

THIS BOOK IS PRODUCED IN COMPLETE CONFORMITY WITH THE AUTHORISED ECONOMY STANDARD

ROSE & CARLESS
MANUAL OF
SURGERY

For Students and Practitioners

BY

CECIL P. G. WAKELEY, C.B.
D.Sc., F.R.C.S., F.R.S.E., F.R.S.A., F.A.C.S., F.R.A.C.S.
Fellow of King's College, London
SENIOR SURGEON, KING'S COLLEGE HOSPITAL; DIRECTOR OF SURGICAL STUDIES AND LECTURER IN SURGERY, KING'S COLLEGE HOSPITAL MEDICAL SCHOOL; SURGEON, BELGRAVE HOSPITAL FOR CHILDREN AND WEST END HOSPITAL FOR DISEASES OF THE NERVOUS SYSTEM; CONSULTING SURGEON, MAUDSLEY HOSPITAL AND TO THE ROYAL NAVY AND EMERGENCY MEDICAL SERVICE; HUNTERIAN PROFESSOR, ROYAL COLLEGE OF SURGEONS OF ENGLAND; CHAIRMAN OF THE COURT OF EXAMINERS, ROYAL COLLEGE OF SURGEONS; EXAMINER IN SURGERY TO THE UNIVERSITIES OF CAMBRIDGE AND DURHAM; FORMERLY EXAMINER IN SURGERY TO THE UNIVERSITIES OF LONDON, GLASGOW, BRISTOL AND TO THE NATIONAL UNIVERSITIES OF IRELAND AND WALES
Temporary Surgeon-Rear-Admiral

AND

JOHN B. HUNTER, M.C.
M.Chir. Cantab., F.R.C.S. Eng.
SURGEON, KING'S COLLEGE HOSPITAL; LECTURER IN SURGERY, KING'S COLLEGE HOSPITAL MEDICAL SCHOOL; SURGEON, ROYAL CHEST HOSPITAL; CONSULTING GENERAL SURGEON, THROAT, NOSE AND EAR HOSPITAL, GOLDEN SQUARE; EXAMINER IN SURGERY TO THE UNIVERSITY OF CAMBRIDGE, AND TO THE SOCIETY OF APOTHECARIES OF LONDON

SEVENTEENTH EDITION
VOLUME I

LONDON
BAILLIÈRE, TINDALL AND COX
7 & 8 HENRIETTA STREET, COVENT GARDEN
1947 (*reprint*)

First Edition, May, 1898.
Second Edition, September, 1899.
Hungarian Translation.
Third Edition, September, 1900.
Fourth Edition September 1901.
Fifth Edition, August, 1902. *Reprinted, September,* 1904.
Sixth Edition, August, 1905. *Reprinted, April,* 1907.
American Edition, August, 1905. *Reprinted, November,* 1906
Seventh Edition, September, 1908. *Reprinted, May,* 1910.
American Edition, September, 1908. *Reprinted, July,* 1910.
Chinese Translation.
Eighth Edition, September, 1911. *Reprinted, April,* 1913.
American Edition, August, 1911. *Reprinted, August,* 1912.
Arabic Translation.
Ninth Edition, October, 1914. *Reprinted, August,* 1916; *September,* 1917
March and August, 1918; *January,* 1919.
American Edition, October, 1914.
Tenth Edition, January, 1920: *Reprinted, July,* 1921; *May,* 1922; *June* 1922.
American Edition, January 1920.
Second Chinese Edition, June, 1922.
Eleventh Edition, August, 1924.
American Edition, August, 1924
Third Chinese Edition, November, 1924
Twelfth Edition, August, 1927.
American Edition, August, 1927.
Thirteenth Edition, August, 1930.
American Edition, August, 1930
Fourteenth Edition, August, 1933.
American Edition, August, 1933
Fifteenth Edition, May, 1937.
American Edition, May, 1937.
Sixteenth Edition, July, 1940. *Revised, reprint March,* 1943.
American Edition, July, 1940.
Seventeenth Edition March, 1943. *Reprinted September,* 1944; *January,* 1947.

PRINTED IN GREAT BRITAIN

The bust of Lord Lister now in the Royal College of Surgeons of England. It was made posthumously and is the work of Sir Thomas Brock. The photograph is taken from a copy in the National Portrait Gallery.

TO

LORD LISTER, LL.D., F.R.S.,

President of the Royal Society,

THE FATHER OF ANTISEPTIC SURGERY,

THIS WORK IS, WITH PERMISSION,

Dedicated by the Authors,

IN GRATEFUL ACKNOWLEDGMENT OF THE MANY ADVANTAGES

THEY HAVE DERIVED

WHILST ASSOCIATED WITH HIM IN HIS WORK

AT KING'S COLLEGE HOSPITAL.

This dedication is a facsimile of the original dedication which appeared in the First Edition in 1898

PREFACE TO THE SEVENTEENTH EDITION

This seventeenth edition is the second edition to be published during the present war, and practically forty-five years have elapsed since the first edition made its appearance. So the book is well on its way towards its half-century.

The book has been revised, but not as thoroughly as we should have liked, for war-time activities, the difficulty of printing and the shortage of paper have all contributed to the difficult task of thorough revision. Nevertheless, whole sections have been re-written and extended in this edition, including blood transfusion, war burns, blast, compression syndrome, and war surgery.

Numerous new illustrations have been added, and these all come from the able pen and brush of Mr. A. K. Maxwell.

The war is now well into its fourth year, and new methods which have stood the test of time and experience have been incorporated in this edition.

To members of the medical branches of the fighting forces, the Emergency Medical Service, and to those who are about to join one of these branches, either at home or abroad, this book covers all their many and varied requirements, and to them it should continue to be a standard reference book, as also it has been to many generations of general practitioners in every part of the British Empire and in the United States.

Diagnosis, treatment and post-operative arrangements are each clearly described; prognosis is also indicated in most cases. Where treatment other than operative treatment is available it, too, is given and, where necessary, alternative methods are described.

The preparation of the patient for operation is included, and guidance with regard to the use of anæsthetics is given in such cases as require specific information, in addition to the general instruction to be found in the chapter on Anæsthetics.

Surgeon-Commander G. P. McCullagh has given me great help in the preparation of this edition, and I wish to tender him my very grateful thanks. I also wish to thank all those surgeons both at home and abroad who have given me useful advice and criticism on many and varied surgical subjects. This advice has been most valuable, and is very much appreciated.

And, finally, my thanks are due to the publishers for their real interest in the book and for all the care and attention they have given to it in its passage through the press at a time which must have been the most troublesome in history.

CECIL P. G. WAKELEY.

14, Devonshire Street,
Portland Place,
London, W.1.
January, 1943.

CONTENTS

LIST OF PLATES

A MANUAL OF SURGERY

CHAPTER I.

INFECTION—IMMUNITY AND SUSCEPTIBILITY.

A KNOWLEDGE of bacteria and of the infective processes which are associated with their activities is of primary importance to the surgeon. Many surgical diseases are due, in the first place, to the action of bacteria, while many others follow their entrance into the body through wounds. Hence the necessity for a familiar acquaintance with the distribution and mode of life of the more important species of bacteria and the mechanism by which they give rise to morbid processes in the human body. A practical ability to apply this knowledge in the matter of diagnosis and treatment is essential; but for this purpose a detailed study of Pathological Bacteriology is not necessary here, and we shall therefore confine ourselves to the more general considerations of the subject in so far as they are referable to surgical practice.

Bacteria, their Morphology and Physiology.—Bacteria are the most widely distributed of all living organisms. They are minute structures, measuring, usually, less than 1 μ, and possessing a definite form which consists of a tiny particle of cytoplasm surrounded by a cell wall. They vary in shape and size, and in this respect are commonly grouped under three main headings: (1) **the Coccus**, having a globular form; (2) **the Bacillus,** in the shape of a short rod; (3) **the Spirochæte,** possessing a true spirality or series of undulations.

The Coccus.—There are many varieties of cocci, but the more important members of this group consist of the following:

(1) **The Diplococcus,** or cocci arranged in pairs, *e.g.* the pneumococcus or gonococcus.

(2) **The Staphylococcus,** or cocci occurring in bunches. This organism is the common causal agent to be found in localized suppuration.

(3) **The Streptococcus,** or cocci growing in the form of a chain. Of this variety there are two main sub-groups—namely, **Hæmolytic** and **Non-hæmolytic** organisms, depending on whether they do, or do not, possess the ability to hæmolyze the red blood corpuscles. The former is of great surgical importance and is commonly found in most types of spreading inflammation with or without suppuration.

The Bacilli.—These are short, straight, rod-shaped organisms with rounded or square ends. They may be motile or non-motile and may

possess flagellæ. Many surgical diseases are associated with their activities and will be referred to in their respective places. Occasionally the rod is curved, in which case it is termed a 'spirillum' or 'vibrio.' There is only one type of vibrio which is of surgical importance, and that is the *vibrio choleræ*, the organism which is the cause of Asiatic cholera.

The Spirochætes.—These are less numerous than the bacilli. From the surgical standpoint there are two only of importance—namely, the *Spirochæta pallida*, or organism of **Syphilis**, and the *Spirochæta pertenue*, the organism of Yaws.

Conditions of Bacterial Life.—Bacteria respond to environmental conditions in the same way as other living organisms and may, therefore, be subject to a variety of influences. In circumstances adverse to their growth or welfare, many species, usually bacilli, undergo what is termed **spore-formation.** This process consists of the development of a minute highly refractile body in the protoplasm of the bacterium to which the vital characteristics of the organism are transferred. In favourable circumstances it will reassume its original form. Spores possess the notable feature of possessing a great resistance to damaging external influences, such as extremes of heat and cold or prolonged immersion in solutions of antiseptic and are, therefore, liable to constitute a source of infection if great care is not taken in the course of sterilization.

There are three main environmental factors which are concerned in the development of bacteria—namely, temperature, oxygen and food requirements. With reference to temperature it may be said briefly that bacteria grow best at or about body heat (37° C.), but will also thrive within the limits of 15° C. and 42° C. Beyond these degrees growth is uncommon, but these temperatures will not destroy spores, which, in some cases, are capable of surviving boiling for several hours, although they are effectively killed by steam at high pressure in an autoclave within twenty minutes. Hence it is fortunate that very few spore-forming bacilli are pathogenic to man, the main exceptions being the organisms which produce tetanus, anthrax and gas-gangrene. It may be stated here that light is also injurious to bacteria; this is especially the case with the tubercle bacillus, which succumbs after a short exposure to direct sunlight. Hence the importance of well-lighted rooms in the treatment of sickness.

Taking next the question of oxygen requirements, it may be stated that many pathogenic organisms require **free oxygen** for their development, and are then spoken of as being **aërobes.** In other cases a few, such as the tetanus bacillus, will grow only in the complete absence of oxygen, ceasing to develop, though remaining alive, when that gas is admitted; such organisms are called anaërobes and derive their oxygen from those compounds in the surrounding medium which contain it.

Bacteria which grow best in air, but which will also grow in its absence, are called facultative anaërobes, and those which grow best under anaërobic conditions, but are capable of some growth in presence of oxygen, are called facultative aërobes. In the living body both strict aërobes and strict anaërobes are capable of growth. Moreover,

a strict anaërobe may grow in a fluid freely exposed to air in the presence of other organisms which have a great affinity for oxygen and rapidly absorb it. In this way tetanus bacilli may flourish even in superficial wounds, if such other bacteria are present.

With regard to food, bacteria make use of organic nitrogenous compounds for their development, obtaining these from the decay or decomposition products of animal and plant life or from their excretions. It has been customary to class bacteria as being either **parasitic,** *i.e.* thriving on live tissues, or **saprophytic,** meaning those which will develop on dead material. The distinction is really artificial, as the majority of parasitic bacteria can be cultured in a test-tube, and, on the other hand, organisms which are commonly saprophytic may sometimes produce pathological alterations *in vivo*. In addition to food requirements, all bacteria need a certain percentage of moisture for their growth. Both absolute dryness and pure water (on account of osmotic difficulties) will cause bacteria to die in a few hours or days, although some, *e.g.* the tubercle bacillus, are very resistent to dryness, and anthrax spores have been known to germinate after exposure for a period of ten years.

Mode of Action of Bacteria.—When pathogenic organisms are introduced into the tissues and establish themselves therein, two pathological processes are set in motion—namely, one consisting of local alteration at the site of inoculation which is termed the **local infective process,** or **infection,** and the other consisting of general systemic effects, or **intoxication.** Both these processes result from the presence of toxins which are evolved by the bacteria, but there are also two other factors which play a part in the production of general ill-effects. One of these is the formation of toxic products from the tissues as a result of bacterial activity which become absorbed into the blood-stream. The other factor is occasioned by the passage of the micro-organisms themselves into the circulation, giving rise to the condition known as **septicæmia.**

Toxins are divided into two distinct classes: (*a*) Certain organisms, of which the most important are the bacilli of tetanus and diphtheria, produce soluble **exotoxins** which accumulate in the fluid in which they are grown, and not in the bacterial cells. (*b*) In the case of many other organisms, the specific poison appears to be contained within the bodies of the bacteria; they are known as **endotoxins.** For example, the soluble products secreted by the tubercle bacillus have but little toxic action, whereas the bodies of the bacilli themselves are extremely poisonous.

The pathological effects of these toxins are highly diverse, but in nearly all cases they include the production of fever. Some are selective in their action, affecting only a certain class of cell, *e.g.* the cells of the central nervous system in the case of tetanus. Others, such as those of the pyogenic bacteria, affect any tissues they may happen to reach. Under natural conditions the results vary with the amount of toxin present in the body, and with the susceptibility of the animal and of the tissues in question. Thus a very powerful toxin may immediately destroy the vitality of a part *en masse*, whilst one

that is somewhat less intense in its action may kill the tissues after causing an acute inflammation. In another group of cases the inflammation may produce the slower but progressive death of the tissues, followed by suppuration or by fibrosis. A similar but usually slower process leads to necrotic caseation; or, if a very feeble toxin acts for prolonged periods, it may serve as a stimulant to the growth and proliferation of the fibrous tissues, etc., without the development of any external signs of inflammation. Certain organisms, especially some of the streptococci, possess also the power of breaking up the red blood-corpuscles (hæmolysis), and as a general rule the hæmolytic variety of bacteria are more dangerous than the *non-hæmolyzing type*. It follows, therefore, that the local infected process will be well developed when the infection is caused by organisms which are characterized by the formation of intra-bacterial poisons, or endotoxins, with a tendency to remain localized; thus a boil (which is a localized staphylococcal abscess) may be associated with few or no general symptoms. On the other hand, an infection with a virulent streptococcus may give rise to a fatal septicæmia in a few days without producing any marked local change. In other cases the organism, *e.g.* tetanus, is of the type that does not produce much local reaction, as it gives rise mostly to soluble exotoxins which are absorbed by the blood-stream. But in general it may be said that the two processes of local tissue alteration and generalized ill-effects are much more evenly balanced, although one feature usually predominates more than the other.

The question of **virulence** is one of the greatest importance, since differing strains of the same organism may vary much in the degree of virulence, as may also the same strain under varying conditions. Thus, rabbits are often but little affected by the injection of large amounts of a pure culture of some particular strain of *Streptococcus pyogenes*, and yet it is possible so to exalt the virulence of this strain that an extremely small dose may produce death. This exaltation of virulence is usually accomplished by 'passage' through a series of susceptible animals; the disease appears more rapidly and runs its course more acutely in each successive animal, up to a certain point of maximum intensity, which may then persist. Probably something of the sort occurs under natural conditions, for an organism taken directly from a patient is usually much more virulent than one that has been cultivated in the laboratory. Thus even a slight accidental wound incurred by the surgeon or pathologist during an operation or post-mortem upon a case of, say, streptococcal peritonitis may lead to a very rapid and severe infection, indicating a very high degree of virulence in the organism.

Cultures of an organism of diminished virulence are said to be 'attenuated.' The artificial attenuation of pathogenic bacteria is a subject of great importance in connection with the production of immunity, and it may be laid down as a general rule that the cultivation of an organism under slightly disadvantageous conditions tends to diminish its virulence, and *vice versa*. For example, much work has recently been carried out in connection with the production of

diminished virulence of tubercle bacilli (see p. 175). The anthrax bacillus grows best at 37° C., and retains its virulence for long periods at this temperature, but if it is cultivated for several weeks at 42° to 43° C. it becomes attenuated. Cultures thus treated constituted Pasteur's vaccine against anthrax; when injected into animals it caused transient ill-effects, but the animal became immune to the disease. The gonococcus is another organism the vitality of which is much influenced by heat. Growing best at a temperature of about 36° C., and capable of growth between 25° and 38° C., cultures are injuriously affected by a temperature of 40° or 40·5° C., and inasmuch as the normal tissues are not seriously harmed by such a degree of heat, it is possible to employ diathermy with the object of raising the local temperature of parts such as the prostate, cervix uteri, or deep urethra, as well as of joints, when infected with these organisms, and thereby attenuating their activities, and enabling the tissues to deal effectively with them. Similarly, growth in a resistant animal also tends to produce attenuation of the causal organisms of certain diseases.

The organism must be **pathogenic** if infection is to occur, and by this we mean capable of producing disease in the animal in question. Thus, the inoculation of the gonococcus into the urethra of the lower animals leads to no results, and infection does not take place. Hence two factors must be present: the organism must be virulent and the host susceptible.

Lastly, an essential feature of infection is that the toxins of the organism must act on the tissues of the host. Thus, it is quite possible, and not uncommon, for streptococci to be present in the outer layers of the skin, and the diphtheria bacillus in the mouth, etc., and yet for no harmful effects to arise, since either the organisms do not form toxins, or else these toxins do not affect the tissues. This is not technically 'infection,' although in such cases any slight lesion or any condition leading to local or general lowering of resistance may bring it about.

The terms **specific** and **non-specific** as applied to infective diseases also require explanation. A specific disease is defined as one which is always produced by a particular species of micro-organism, and by no other. Thus, tetanus is a well-marked pathological entity, always due to *Clostridium tetani* (bacillus tetani), and may be taken as the type of a specific infection. Suppuration, on the other hand, is caused by many different species of bacteria, and is therefore termed non-specific. The boundaries of these divisions are constantly changing with the advance of pathological research, and certain diseases which were previously regarded as homogeneous may thus come to be split up into specific groups, each due to its own organism.

Immunity and Susceptibility.

In ordinary circumstances all living animals are constantly exposed to possible sources of infection. The ability to withstand these attacks depends upon the degree of resistance to infection which is possessed by the individual. This quality of resistance is termed 'immunity,'

and is of two kinds, depending on whether it is possessed naturally, in which case it is called 'natural immunity,' or whether it has been acquired. Man possesses the natural immunity to many diseases, in particular those which affect animals; but there is no absolute standard of immunity, since the reaction of the tissues may vary between the highest degree of susceptibility and the highest degree of immunity. Thus, if several animals are inoculated with equal doses of the same bacterial culture, one may show no ill-effects; another may exhibit a slight amount of inflammation at the site of inoculation; a third may acquire a spreading inflammation, which may progress to suppuration or gangrene; whilst a fourth may develop a fatal general infection. Further, an animal may be immune to an organism of ordinary virulence, although susceptible to the same organism when its virulence is exalted.

Immunity is influenced by a variety of factors, which, in brief, may be said to comprise anything which tends to lower the vitality of the individual in general or of the tissues locally. Of general causes may be mentioned such factors as exposure to wet and cold, malnutrition, chronic alcoholism and certain constitutional diseases, such as diabetes and Bright's disease. Local causes would comprise all conditions capable of producing local damage to the tissues, such as burns or bruises, and all forms of irritants including foreign bodies and strong antiseptics. In addition one may add that a defective supply of fresh blood, whether due to disease of the bloodvessels or to venous stagnation, due to tight bandaging or pressure, will also appear less resistant to infection.

Acquired Immunity is of two kinds—active and passive.

Active immunity results from a previous attack of the disease, from a subinfection or repeated-subinfections with a dose of organisms too few in numbers or too low in virulence to cause any appreciable disease, or, thirdly, from artificial inoculation. The exanthemata are good illustrations of diseases conferring an active immunity. The permanence of the resulting immunity varies greatly. With some infections, such as small-pox, second attacks of the disease are very rare, and the immunity is, as a rule, complete and lifelong. With other infections, such as those due to pneumococci or streptococci, the immunity tends to be of short duration. All intermediate grades are found.

The following are the most important artificial methods of producing active immunity: (1) Inoculation of the disease as it occurs in Nature. This is of course a dangerous method, since the attack may be as severe as one acquired in the normal way. Before the introduction of vaccination it was formerly practised in the hope of preventing a more severe attack of small-pox. (2) Inoculation with the causal micro-organism in an attenuated condition. Pasteur applied this method in the prevention of anthrax in sheep and cattle, the 'vaccines' employed being living cultures of *B. anthracis* attenuated by growth at 42° to 43° C. (p. 5). He also employed an attenuated virus for the prevention and treatment of hydrophobia (p. 129). In the case of vaccination against small-pox, the lymph employed con-

tains a living virus (whether that of small-pox itself in an attenuated condition, or of a closely allied disease, being not yet finally established). For a description of Calmette's B.C.G. vaccine, consisting of attenuated tubercle bacilli, see p. 175. (3) Injection of dead cultures of bacteria is used in the preventive inoculation against plague (Haffkine) and against typhoid and paratyphoid fevers (Wright), as well as for the prevention and treatment of many other infective conditions. The cultures are killed, usually by heat, and small doses injected subcutaneously, or sometimes intramuscularly or intravenously. The result may be a local inflammatory reaction of varying severity, together with general symptoms, such as fever and malaise. When these have passed off, the patient has acquired some immunity to the disease, so that he is now able to withstand the injection of larger doses, by which means the immunity is still further increased. (4) Injection of the extracellular toxins of the causal organism is of great value in immunizing the lower animals for the preparation of curative sera, especially antidiphtheritic and antitetanic. The horse is usually chosen for this purpose, since it yields a large amount of serum at each bleeding. The principle of the method is simple. A small quantity of the toxin (which has been filtered to remove living bacteria) is injected subcutaneously. It causes local inflammation, fever, and malaise; but, when these have subsided, another and slightly larger amount of toxin can be tolerated. In this way the dose is gradually increased until the animal is so resistant that the injection of enormous doses of most powerful toxin will produce but slight and transient ill-effects. In actual practice this method is usually modified, the earlier stages being considerably shortened by the injection of a mixture of toxin and antitoxin, or by the use of peculiar forms of toxin of diminished activity. A satisfactory method of immunizing the human subject to diphtheria has been found in the injection of a mixture of toxin or modified toxin and antitoxin. Similar methods in the active and passive production of immunity are now also employed in scarlet and other acute infective fevers. A staphylococcus toxoid or modified toxin has recently been under trial, apparently with some success.

It will be noticed that in all these methods the animal which subsequently becomes immune combats and overcomes the organism or its toxin. For this reason it is termed an active immunity, *i.e.* it is acquired by the animal's own active struggle against and victory over the bacteria or their products.

Passive immunity is that which is conferred on an animal without effort on its part by the injection of serum from an animal that has already acquired an active immunity against the disease in question. For example, if some of the serum from a horse which has been actively immunized against tetanus is injected into a second horse (or other animal), the latter will also become temporarily immune. The second animal is now found to be protected by the injection of the serum of the first animal, and is not rendered ill by the further injection of toxin, *i.e.* it is merely the passive recipient of protective substances which have been elaborated by the first. The fact that the injection of these

sera into man sometimes causes transient ill-effects, such as fever, joint-pains, rashes, etc., in no way modifies the truth of this statement: these phenomena do not always occur, but, when found, are due, not to the protective substances, but to the foreign serum-proteins injected with them.

Passive immunity cannot be bestowed by the injection of serum from an animal which is naturally immune: most of the lower animals, for example, are naturally immune to syphilis, but their serum has no protective or curative action in man. The diseases in which the serum has the greatest practical value for protection or cure are those in which the specific micro-organisms produce extracellular toxins, especially diphtheria and tetanus, and also bacillary dysentery, botulism, gas-gangrene, etc. The serum of patients who have recently recovered from certain of the acute infective fevers, such as measles, chicken-pox, whooping-cough, scarlet fever, poliomyelitis, and many other analogous diseases, is now also successfully used. In certain diseases, the patient's own serum may be employed for this purpose; *e.g.* in meningococcal meningitis (when it is injected into the cerebro-spinal theca); or (after the intravenous injection of salvarsan or one of its allied drugs) in neurosyphilis ('salvarsanized serum').

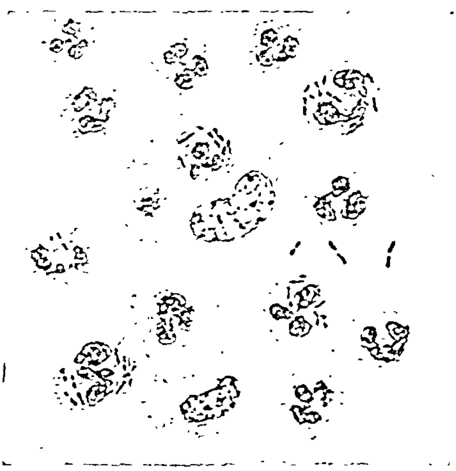


FIG. 10.—PHAGOCYTOSIS OF *Bacterium coli* BY CELLS OF PERITONEAL EXUDATE, TWENTY-FOUR HOURS AFTER INFECTION.

The polymorphonuclear leucocytes (pus-cells) present in large numbers are actively ingesting the organisms, whilst the mononuclears, probably derived from the peritoneal endothelium, are englobing the pus-cells. (× 1,000).

Active and passive immunity also differ from one another in other respects. Passive immunity is produced immediately the serum is injected, whereas active immunity is only developed slowly after the injection of the toxin, or of the living or dead culture; in general, a week at least must elapse before the full degree of immunity is produced. Again, passive immunity lasts a comparatively short time, unless, of course, the dose of the immunizing serum is repeated. In the case of prophylactic injections of antidiphtheritic or antitetanic serum in man, the duration of the immunity is probably less than a month.

Mechanism of Immunity.—This depends upon the ability of the body to form antibodies which are capable of destroying the bacteria and rendering them suitable for ingestion for the leucocytes (see Fig. 10). The process is complicated and many factors are involved. The student, therefore, should refer to special manuals which deal with the subject in order to acquaint himself with the details. In

brief, it may be stated that a contest which may be very prolonged is waged between the bacteria and the defensive forces, and may result in much damage to the tissues. Thus it follows that the body must also possess the power of repairing the damage caused or at least of patching up the injured parts, a process which will be referred to again in connection with the pathology of inflammation. The practical applications of the phenomena of immunity are twofold: diagnostic and therapeutic.

The chief examples of their **diagnostic application** are (*a*) the agglutination reaction in the diagnosis of typhoid, paratyphoid, the undulant (Mediterranean or Malta and abortus, etc.) and other fevers, bacillary dysentery, etc.; (*b*) the complement-fixation test in syphilis (the Wassermann reaction), tuberculosis, gonorrhœa, and a few other diseases; and (*c*) the use of toxins in the diagnosis of particular diseases, such as tuberculosis, diphtheria, and scarlet fever. Introduction into a patient suffering from a particular disease of some of the toxin of the specific organism which causes that disease often gives rise to local inflammation or general disturbance. Thus in a tuberculous subject hypodermic injection of a small quantity of 'old tuberculin' (the concentrated filtrate of a broth culture of the tubercle bacillus) may cause a sharp rise of temperature, and sometimes headache, shivering, and pains in the limbs. The same preparation scratched into the skin gives rise to local inflammatory reaction (von Pirquet's test, p. 171), or, if dropped into the eye, causes severe conjunctivitis (Calmette's test). A similar reaction is induced in those who are susceptible to diphtheria infection by introducing into the skin a small quantity of diphtheria toxin (the Schick test), and also in those susceptible to scarlet fever by the intradermal injection of the toxin of the streptococcus scarlatinæ; this is termed the Dick test.

The **therapeutic applications** consist of the prophylactic immunization and the curative treatment of disease, and fall under three main headings:

1. **Vaccines** consist of emulsions of dead bacteria* which are injected —usually subcutaneously, sometimes intramuscularly or intravenously —with a view to influencing beneficially infections in other parts of the body due to a similar organism. Such injections stimulate the defensive powers of the tissues, not merely locally, but generally, the antibodies so produced being thus available in increased amount to antagonize or neutralize the organisms and their products at the site of the disease. It usually happens, however, that the reaction of a living tissue is greater than the stimulus demands, and thus, just in the same way as a fracture frequently leads to a formation of callus greater than is necessary for ultimate repair, so a vaccine results in a development of antibodies greater in amount than is required locally, and the superabundance thus created is available to combat infections in other parts of the body.

The doses of vaccines vary greatly with different organisms; a

* Vaccinia, or cow-pox vaccine, from which the generic term 'vaccine' was originally derived, contains the *living* micro-organism—a filter-passer—of that disease.

normal dose of staphylococci would consist of 500 million or more, but a much smaller dose would have to be employed with other organisms in order to avoid severe local and general symptoms. As a rule the patient acquires some degree of tolerance, and the dose may easily be increased gradually or more rapidly as the treatment progresses. It is always advisable, where practicable, to prepare the vaccine for each patient from the organisms which are attacking him (**autogenous vaccine**), since there are often considerable differences between the various strains of bacteria, and a stock vaccine may not prove efficacious against an infection with apparently the same species.

Of recent years evidence has accumulated to show that, in addition to their action in stimulating the production of specific antibodies, vaccines may also have non-specific effects. Wright and his co-workers and others have shown that, following the subcutaneous or intravenous inoculation of a suitable dose of vaccine, marked increase in the bactericidal power of the blood is produced, which reaches a maximum within about four hours. This bactericidal action is non-specific; an injection of killed staphylococci increases the bactericidal power of the blood against all organisms indiscriminately. This rapid production of bactericidal substances, which have been demonstrated in the laboratory, furnishes us with an explanation of the immediate improvement sometimes seen in febrile conditions after inoculation of a small dose of a vaccine—an improvement which occurs too soon to be due to specific immune bodies. This phenomenon is also utilized in **immuno-transfusion.** A healthy donor of an appropriate blood-group is inoculated with a large dose of a vaccine, which may be of any organism, but usually staphylococci (say 1,000 million) are employed. Five hours later, when the bactericidal substances are at a maximum, the donor is bled, and 500 to 700 c.c. of his defibrinated blood are injected intravenously into an acutely ill patient whose response to his infection is failing. The addition of the healthy leucocytes and blood rich in bactericidal substances may enable him to cope with the infection. A non-specific effect of a vaccine—probably of the nature of protein shock—is also utilized in treatment of some more chronic conditions, such as rheumatoid arthritis, asthma, disseminated sclerosis, etc. Here a large dose of vaccine sufficient to cause a sharp febrile reaction is administered. With the pyrexia is associated a considerable polymorphonuclear leucocytosis; and the beneficial effect seems to be proportional to the severity of the reaction produced.

2. **Antitoxic Sera*** are prepared against the toxins of tetanus, diphtheria, gas-gangrene (*Clostridium welchii*), and some varieties of bacillary dysentery, and also for the treatment of botulism. These, as has already been explained, contain substances which neutralize the extracellular toxins of the organisms in question. It is essential that antitoxic sera in sufficient amount should be administered as early as possible, in order that they may render the toxins inert before

* Various modifications and improvements in the preparation of antitoxic and antibacterial sera have now been introduced, *e.g.* refined and concentrated high-potency forms, separated antitoxin-globulins, etc., for the technical details of which reference should be made to the special literature on the subject.

the latter have combined with and injured the living cells. Time may be saved by intravenous injection, since it has been found that diphtheria antitoxin is not fully absorbed from the subcutaneous tissues for twenty-four hours or more. Antitoxin is most rapid in its action when introduced directly into the circulation, and the intravenous route should therefore be used in the more urgent cases. Absorption after intramuscular is more rapid than after subcutaneous injection, and these routes may be used for subsequent treatment, the effects, although slower, being more lasting.

3. **Antibacterial Sera** contain antibodies which act, not upon the toxins, but upon the organisms themselves, by (1) bactericidal or bacteriolytic action, (2) opsonic action, and (3) agglutination. Of these sera, the most important in surgical practice are:

(*a*) *Anti-streptococcal Serum.*—A polyvalent serum prepared by employing a variety of strains of hæmolytic streptococci (*Str. pyogenes* and its allies) is commonly utilized. A specific antiserum is now also prepared against the streptococcus of scarlet fever, for prophylactic and therapeutic, as well as diagnostic, use; and sera are also made against special strains of streptococci, *e.g.* those isolated from cases of puerperal septicæmia, or of erysipelas.

The dose of serum may be 25 to 50 or 100 c.c., administered intravenously, intramuscularly, or subcutaneously, according to the urgency of the case, and this may be repeated as often as necessary.

(*b*) *Anti-anthrax Serum.*—This has given excellent results in the treatment of localized anthrax (malignant pustule), and the improvement is often manifested within twenty-four hours. It should be given intravenously in large doses.

(*c*) *Anti-pneumococcal Serum.*—Much work has been recently carried out on the typing of pneumococci and the preparation of sera specific against these types. Felton's refined and concentrated serum is, so far, the most satisfactory product, both Type I. and Type II. pneumococcal infections, especially the former, being amenable to treatment with it. The treatment of Type III. infections with serum has not yet been successful, and further work is required upon antisera for these and also infections due to the heterogeneous Type IV. group, which has now been subdivided into a large number of further types.

(*d*) *Anti-dysentery Serum.*—The action of this serum is probably partly antitoxic and partly antibacterial. It is usually prepared in polyvalent form, and may be used for the treatment of ulcerative colitis due to dysentery bacilli.

(*e*) *Anti-meningococcal serum* is given intrathecally and intravenously for the treatment of cerebro-spinal meningitis due to meningococci.

(*f*) An *anti-staphylococcal serum* is under trial, as are also numerous other sera.

Anaphylaxis and the closely allied phenomenon known as **allergy** are conditions of supersensitiveness to various foreign proteins, such as the serum of another animal, egg-albumen, grass-pollen, etc. Supersensitiveness manifesting on the administration of a subsequent dose of an antiserum is usually the result of an injection ten or twelve days or more previously of serum from the same species of animal

(commonly the horse), and depends on the ordinary serum proteins, not on the antibody content. If a minute quantity (0·01, 0·001, or even, in some cases, only 0·000001 c.c.) of horse serum be injected into a guinea-pig, the animal will become sensitized to horse serum. If, after an interval of usually not less than twelve to fourteen days, a second dose of 5 c.c. (non-toxic to a normal guinea-pig) be then injected intraperitoneally, or one-tenth of that dose intravenously (subcutaneous injection being more uncertain in its results), the condition of acute anaphylactic shock rapidly supervenes with collapse, dyspnœa, and frequently death. The symptoms appear to be due to a toxic effect on smooth muscle. Man is much less susceptible than the guinea-pig, but anaphylaxis may occur as the result of an injection ten days to six months or more before, or rarely in horse-asthma patients with no history of previous injection. Acute anaphylactic shock in man causes extreme distress, with dyspnœa, cyanosis, and collapse; death may ensue, but the number of fatal cases on record is very small. If there is any reason to suspect supersensitiveness, the patient should be tested beforehand by injecting intradermically, not hypodermically, a small amount, *e.g.* 0·1 c.c., of the serum. If no urticarial or erythematous reaction occurs round the site of injection within forty minutes, the administration may be proceeded with; but, should a positive reaction, which usually occurs in from five minutes to half an hour, be obtained, desensitization must first be effected. If there is no urgency, 0·025 c.c. of serum, suitably diluted with saline, should be administered hypodermically, and the dose should be doubled every half-hour. If no reaction follows when the amount of 1 c.c. is reached, the following doses are given intravenously, beginning with 0·1 c.c., and doubling the dose every half-hour until the total amount of, say, 25 c.c. has been given. In urgent cases, *e.g.* in tetanus, a more rapid method must be adopted, even though it entail some risk. A War Office Committee recommended the following method: 5 c.c. of the serum are diluted with 50 c.c. of normal salt solution. Of this mixture, 1 c.c. is injected intravenously, followed four minutes later by 3 c.c., two minutes later by 10 c.c., and two minutes later again by 25 c.c. Then in ten or fifteen minutes the full dose may be given intravenously or intrathecally. All such injections must be given very cautiously and slowly. If any reaction occurs during this procedure, the administration must be delayed. In cases where anaphylactic shock has developed, atropine sulphate ($\frac{1}{50}$ grain) or a 1 in 1,000 solution of adrenalin (0·3 to 0·5 c.c. or 5 to 8 minims) should be given intravenously in 10 c.c. of sterile normal saline.

Serum Disease, apart from the more serious phenomena described above under Acute Anaphylaxis, is another condition which may follow the administration of a foreign serum, and is probably an analogous phenomenon. Its frequency and intensity are in direct relation to the volume of serum given. The first symptom is usually an urticarial or erythematous rash, which appears between the seventh and tenth day, at the site of injection, and may become generalized. This may be accompanied by malaise, slight fever, adenitis, pains in

the joints perhaps with effusion, and albuminuria. The condition causes considerable discomfort, but is never serious, and recovery occurs within a few days. It is stated that intravenous injection of 1 to 2 c.c. of the patient's own serum causes rapid disappearance of the symptoms, but this is not reliable. Calcium lactate in 15-grain doses at the time of the injection and for a day or two subsequently may be given as a prophylactic measure, but is not of great value. Otherwise the treatment is purely symptomatic. An **immediate** reaction may occasionally supervene after a **second** injection, almost at once or within six hours; or an **accelerated** reaction may occur between the eighteenth hour and the fifth day, with the appearance of rash, joint-pains, vomiting, pyrexia, and even convulsions and collapse.

Allergy, which is a condition probably closely allied to anaphylaxis, is the supersensitiveness, exhibited by some patients suffering from certain diseases, to the products of the corresponding organism, *e.g.* tuberculin or mallein in tuberculosis and glanders respectively. This state is probably gradually produced by the bacterial products set free within the body of the patient; and, in a similar way, hay-fever, and hypersensitiveness to various food-proteins both animal and vegetable, hairs, feathers, and other epidermal structures or débris of animals, etc., are probably due to previous sensitization by the absorption of grass-pollen, etc., or the other foreign proteins involved. In certain cases, the condition of supersensitiveness appears to be natural, rather than acquired. It may be hereditary, and run in families, and it may take different forms in the different members of such families.

CHAPTER II.

INFLAMMATION AND REPAIR.

THESE two series of processes are so intimately associated with each other that no advantage is gained by endeavouring to describe them separately. In this series of processes sometimes one set, sometimes the other, may predominate, but in most cases a more or less definite sequence of events may be observed.

'Inflammation is the succession of changes which occur in a living tissue when it is injured, providing the injury is not of such a degree as at once to destroy its structure and vitality.' Such was the definition given in 1870 by Burdon Sanderson, and it is sufficiently accurate if it be remembered that the term 'injury' includes bacterial invasion; and that the 'succession of changes' is presumed to appear soon after the application of the injury. If such injury has not completely destroyed the vitality of the tissues or killed them outright, changes occur in and around the injured area, by which Nature endeavours to limit and localize the effects of the irritant; to antagonize, eliminate, or enclose it if still present; and to make good the damage, either by restoring the tissues to normal or patching them up as far as possible—casting off the débris if at a surface: absorbing and removing it if within the body; or, if this cannot be completely accomplished, transforming it to, or enclosing it by, fibrous tissue within the living tissues. In the past, a great variety of opinions existed as to the position of the dividing line between inflammatory and reparative processes. Occasionally the tissue reaction called into existence by bacterial invasion is so severe as to increase, rather than diminish, the risks of the patient.

The **causes** of inflammation are numerous and varied, and most frequently are infective in nature. We have already alluded (pp. 6-8) to the conditions, local and general, which predispose an individual to such invasion, and render him more liable to an inflammatory attack. Apart from bacteria, inflammation may be set up by (*a*) mechanical lesions, such as blows, sprains, tension, pressure, etc.; (*b*) burns or scalds; (*c*) toxic substances, such as acids, alkalies, irritating vapours or gases, or vegetable and animal poisons; (*d*) the action of the electric current; and (*e*) the irritating influence of X-rays, radium emanation, sunlight, ultra-violet rays, etc.; and (*f*) new growth.

The actual **phenomena** of inflammation may be studied in the web of a frog's foot. If this is spread out and examined under the microscope, the following evidences of normal physiological activity may be seen: (*a*) the flow of blood through the vessels (Fig. 11), as indicated by the movement of the formed blood-elements—the red

corpuscles, each separate from the other, flowing in the central or axial current; the leucocytes occasionally seen amongst the red, or here and there one may be noticed being carried slowly along in the more or less corpuscle-free peripheral portion of the stream; and (*b*) the constant rhythmical changes in calibre of the arterioles independent of the heart's action, and aiding the flow through the capillaries.

Acute Inflammation.

I. **Vascular Changes.**—The first change to be observed, after a momentary contraction of the arterioles, is a state of active hyperæmia, due to a dilatation of the bloodvessels. This state of hyperæmia is accompanied by an increased rate of blood-flow (**acceleration**), and is succeeded in turn by a slowing (**retardation**) of the blood-stream, which may progress to a state of **stasis,** after passing through a short phase of **oscillation,** during which the corpuscles sway backwards and forwards before reaching a final state of standstill. During this period of alteration, the formed elements of the blood change their relations, the leucocytes and platelets tending to collect in the periphery of the stream, leaving the red blood-corpuscles to occupy the centre of the channel (see Figs. 11 and 12). Later the leucocytes pass through minute interstices in the swollen vessel walls by means of an amœboid type of movement and proceed to the site of inflammation. This process of **migration** (*diapedesis*) to the inflammatory area is brought about by some power of attraction which is exercised by the focus of inflammation, and which is termed 'positive chemiotaxis.' Occasionally, in virulent infections, the reverse effect is observed, the leucocytes being repelled. After an interval the red blood-corpuscles may follow through the openings left by the leucocytes in the damaged vessel walls, giving rise to small hæmorrhages (petechiæ), or a larger one which is termed an 'extravasation.' The migration of all corpuscles ceases when stasis has been effected and intravascular clotting (**thrombosis**) may then ensue.

The function of the wandering leucocytes would appear to be of a protective type, as the cells will, in a favourable case, actively ingest the bacteria, thereby tending to limit the infection, and will also remove dead tissue from the site of inflammation. This mechanism of ingestion and removal is termed phagocytosis. In less favourable cases the leucocytes may die and become disintegrated, setting free a fibrin ferment which assists in the production of an inflammatory coagulum shortly to be described.

Another factor to be observed is the **exudation of lymph,** which becomes evident at a very early stage, the amount and situation of the fluid depending partly upon the nature of the irritant, and partly upon the tissue or tissues affected. This inflammatory œdema may occur into a tissue meshwork, or, if the inflammation is at a surface, it may escape, or may collect, *e.g.* in a body-cavity. This exudation of lymph is merely an exaggeration of a physiological process, but to such an extent that although for a time the lymphatics of an inflamed region

do increased work, yet the transudate is soon greater than they can deal with. If the fluid escapes into the tissues, it may undergo coagulation if it meets the necessary coagulating agents (fibrin-ferment, etc.) developed chiefly from breaking-down leucocytes; inflammatory lymph forms locally, whilst the serum collects in the meshes of the tissues, constituting an inflammatory form of œdema; if there is a sufficient breach of surface, the serum drains away. If the exudation takes place from a serous surface, *e.g.* pleura, peritoneum, synovial membrane, etc., the fluid collects in and may distend the cavity; it is at first spontaneously coagulable, *i.e.* consists of plasma; if coagulation occurs, the clot or plastic lymph either forms an adherent mass on the surface or floats free in the fluid.

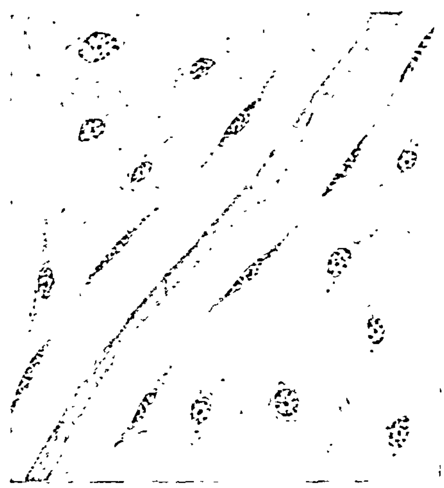


FIG. 11.

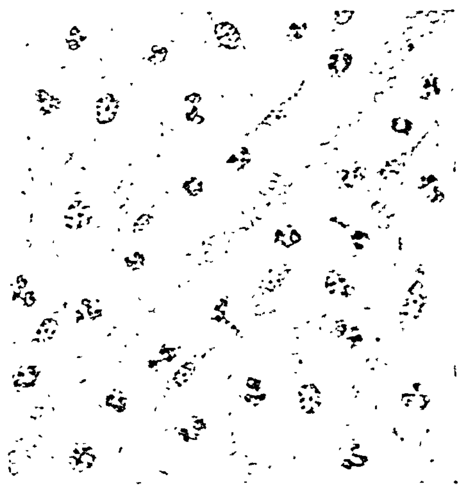


FIG. 12.

THE VASCULAR PHENOMENA OF INFLAMMATION.

On the left is a normal vessel with its peripheral layer free from corpuscles, and its axial stream so rapid that the individual corpuscles cannot be seen. On the right is a similar vessel in a state of inflammation; the blood-current has been retarded so that the individual corpuscles are visible; the leucocytes occupy the periphery of the vessel, and are in process of migration.

Considered, therefore, simply from a vascular point of view, **Inflammation = Hyperæmia + Exudation of Lymph + Emigration of Leucocytes.**

In combating an attack by bacteria and their toxins each of these processes in the inflammatory reaction is of service. The acceleration of the blood-flow brings an increasing quantity of blood to the part, and thereby helps to maintain the nutrition of the tissues at the highest level, so that, if possible, they may be kept alive. It also assists by diluting and washing away the toxins, and provides a supply of antibodies or antitoxins to neutralize the action of the toxins or to destroy the bacteria. The excessive transudation of the plasma may be regarded as an additional means of fulfilling these functions. The value of the retardation and stasis of the blood is less obvious, although

it probably assists the emigration of the leucocytes, which might otherwise find difficulty in attaching themselves to the walls when floating freely in a rapid blood-stream. The extravascular rôle of the leucocytes has already been considered.

II. **Tissue-Changes.**—The reaction of the tissues in **acute bacterial** inflammations depends on the one hand upon the irritative power and nature of the toxins, and, on the other, upon the power of resistance of the patient's tissues. It may be laid down as a general rule that any irritant, if weak enough, *e.g.* when very diluted, acts as a stimulant to the function and growth of cells; on the other hand, if more powerful, it will cause changes varying from slight degeneration up to complete necrosis or death of the tissues.

If the toxins are sufficiently active, death of the tissue may result. This is often brought about by the process termed **coagulation necrosis.** In this condition the tissues and cells become soaked in the coagulable plasma which exudes from the vessels, and the activity of the toxins causes coagulation and death of the whole mass. The result is that, on microscopical examination, structural details are found to be obliterated in the area involved; the nuclei can no longer be stained with hæmatoxylin or other basic dyes, and the tissues now stain uniformly with acid dyes such as eosin. The further history of the lesion depends largely on the nature of the causal organisms. If these are pyogenic, the necrotic mass becomes infiltrated with **polymorphonuclear leucocytes,** many of which may be killed by the toxins, *i.e.* **suppuration** occurs, perhaps with softening and the formation of an abscess (see p. 47).

Mononuclear cells of various sizes and types appear in inflammatory exudates, sometimes earlier, sometimes later, and for the full discussion of the nature and functions of these reference must be made to the larger textbooks of pathology. It is sufficient to state here that the **large hyaline mononuclear cells** may be derived either from the blood or from tissue-endothelial cells. They often appear comparatively early in the course of many inflammatory conditions, especially of serous surfaces, and, as the condition improves, they usually increase as the polymorphs diminish in numbers. They are actively amœboid, and are concerned especially with the phagocytosis and removal of dead cells and débris, though they may also englobe bacteria. Later still, '**small round cells,**' regarded by many as identical with lymphocytes, appear, and may gradually replace the larger mononuclears, from which some believe them to be partially derived, as all intermediate sizes may be found in the same exudate, *e.g.* in a recovering pleurisy or meningitis. These 'small round cells,' and also the closely related 'plasma-cells,' are found especially in chronic inflammations, and particularly in tuberculous and syphilitic conditions.

In any given case, the above-described processes overlap and are intermingled in varying degree; whilst the processes usually classed under 'repair' may also supervene, early or late as the irritant and its effects are overcome and neutralized.

In the more **chronic** inflammations, active cell-proliferation is an

important element in the process, resulting in **fibrosis** and induration of the parts. This affects mainly the interstitial tissues, and the specialized structure of an organ may thereby be impaired.

III. **Lymphatic System.**—It is important to realize the part played by the lymphatic system in the mechanism of inflammation. In the first place it is chiefly by means of the lymph channels that the greater part of the inflammatory exudate is absorbed, and, secondly, the spread of the inflammatory process which occurs in these channels is, in a favourable case, checked by the barriers of lymphoid tissue in the lymphatic glands and subdued. In some cases the lymphatic vessels are attacked during the process and their subcutaneous course becomes visible as a thin red line passing from the site of inflammation to the nearest lymphatic gland. The glands themselves become swollen and tender, and, in certain cases, will break down into abscess formation. In virulent infections it is possible for the organisms to pass through the lymphatic system without giving rise to much local disturbance, and, in such cases, the prognosis is very grave.

IV. **Chronic Inflammation.**—In the chronic type of inflammation, active cell proliferation is an important element, and constitutes the greatest difference between the acute and chronic inflammatory processes. The cells which owe their origin to cell proliferation are derived mainly from the endothelial cells of the vessels, perivascular lymphatics and lymph-spaces; but, in addition to these, there are large numbers of other cells, as in acute inflammation, but they differ in that they are composed mostly of lymphocytes and plasma cells. The former are commonly grouped round the smaller vessels, but are also found in small collections, particularly in the granulomata. The plasma cells are more uniformly disposed through the tissues, and are a more certain indication of chronicity. Vascular changes are much less pronounced, the hyperæmia being much less in degree, although longer in duration. The exudate is more fluid in character, containing comparatively little albumen or fibrin, and in some chronic inflammations of serous membranes the cavities are distended with fluid of a much lower specific gravity than that of blood serum.

V. **The Course of Inflammation.**—This may be extremely variable, as it depends on several factors which are themselves variable. The constitution of the individual, the type and violence of the infecting organism, the nature and site of the tissues involved, and the kind of treatment instituted, are all factors which play an important part in the development of the inflammatory process, but which vary in every individual case. In brief, it may be stated that the fate of the inflammatory process may be determined in one of three ways, namely: (*a*) **Regression or Healing.** (*b*) **Progression or Spread.** (*c*) **Chronicity.** It must, however, be recognized that these three processes are not always discrete, but that they often overlap and may all be present together in a lesion at the one time. For instance, it is not an unusual event to see a wound which is healing rapidly at one end to be breaking down and discharging pus at the other. But it is important for the student to be in a position to appreciate and to

understand what is happening and what might happen in any given wound, and, therefore, the following classification has been adopted as one which will enable him to accomplish this in a simple yet comprehensive manner.

Regression or Healing may take place before or after local destruction of the tissues has occurred. In the first place it is termed '**resolution**'—that is to say, restoration of the part to its natural condition and function without the formation of scar tissue. Naturally enough, this can only take place when the inflammatory process has not proceeded very far, and the phenomena which are concerned in the process will be those of inflammation in a retrograde order—namely, an oscillatory movement, which is first manifested among the corpuscles, and is later followed by a restoration of the blood-stream. The red corpuscles lose their property of adhering to the vessel walls, and many of the surviving leucocytes which are present in the exudate may make their way back into the circulation either through the vessel walls or to a greater extent via the lymphatics; others are disintegrated in the tissue and absorbed. The fluid of the exudate is removed by the lymphatics.

Healing after local destruction of tissue has occurred is termed '**repair,**' and takes place by the removal of dead tissue and its replacement by scar tissue.

(*a*) The first stage in the process consists in an abundant *exudation of small round cells*, chiefly lymphocytes and plasma cells, whose function is to remove dead or damaged tissues, as well as to break up, disintegrate, and finally absorb, any blood-clot. They are derived from the surrounding vessels, and are accompanied by a certain amount of plasma, so that the early manifestations of a slight inflammatory reaction are simulated, and this, if it does not exceed certain limits, is a beneficial proceeding. If much tissue has to be absorbed, or when a foreign body such as a suture is buried, giant-cells are likely to make their appearance. After their work is completed they disappear, either finding their way back into the circulation, or being destroyed by the fibroblasts.

(*b*) The exudation of round cells is soon followed by the appearance of a number of large oval cells with abundant protoplasm and large vesicular nuclei, known as *fibroblasts*. These cells are mainly derived from those composing the tissues of the part, either from the connective-tissue corpuscles or the endothelial cells lining the capillaries, lymphatics, or lymph-spaces. Whatever their origin, they soon form a layer of cellular tissue which lies upon the surface or between the lips of the wound, whilst the previously effused leucocytes disappear.

(*c*) The *vascularization* of this cellular layer forms the next stage in the process. This is brought about by the outgrowth from the walls of the nearest capillaries of solid rods of protoplasm, which appear first as minute buds, but rapidly increase in length, and may be single or double. They soon bend over to unite with similar threads growing out from other capillaries, or with the wall of another vessel, or occasionally they unite with the vessel from which they started. After a time these protoplasmic threads become canalized and a communi-

cation is established between them and the mother vessel, so that blood passes into them. The new capillary wall, at first homogeneous, soon becomes lined with definite endothelial cells, and strengthened by connective tissue derived from the fibroblasts around. By this means a soft vascular tissue is produced known as *granulation tissue*, consisting of loops of capillaries supported by large nucleated cells with a varying amount of intercellular substance, which becomes fibrillated in texture. The capillary loops arise in leashes from small terminal arterioles, and it is to this arrangement that the granular appearance of the developing tissue is due; each granulation, as it arises, is about the size of a pin's head.

(*d*) The *transformation* of this granulation tissue into *fibro-cicatricial tissue* is next proceeded with. The fibroblasts become spindle-shaped, and finally long and narrow, with pointed extremities, which often branch; the nuclei also become long and narrow, and lose their vesicular appearance. Around them is developed a fibrillated structure of a collagenous material, which is finally transformed into the fibrous tissue of the scar; the actual arrangement of this material varies with the physical characters and condition of the wound. By the contraction of these fibres the fibroblastic cells become flattened out and compressed, and the newly-formed vessels constricted, so that as time passes the scar tissue becomes less and less vascular, and consequently firmer and denser, as well as smaller.

Progression or spread of the infection will involve a diffusion of the inflammatory process, which may be local or general, and a necrosis of tissues. Thus the spread of the inflammation locally may be followed by: (*a*) **suppuration,** in which the affected tissues and the exudates are liquefied and transformed into pus, with the formation of an **abscess** which will require evacuation; (*b*) **cellulitis,** a condition in which the inflammatory process spreads diffusely in the subcutaneous tissues with the formation of a sero-purulent exudate (such a condition will need free incision to allow of drainage); and (*c*) **lymphangitis and lymphadenitis,** in which the lymphatics become inflamed and the lymphatic glands become swollen and tender and very often break down into abscess formation. Indications of general spread will be shown by the development of a **septicæmia,** in which the organisms travel in the blood-stream, and **pyæmia,** a condition in which metastatic abscesses develop in different parts of the body. Local destruction of tissue will occur to a certain extent in all the above inflammatory lesions but, when pronounced, may result in **ulceration** when the affected tissues are superficially placed and circumscribed in extent, or in **gangrene** when the destructive process is a more extensive one.

Finally, a state of **Chronicity** of the inflammatory process is the remaining alternative in which the inflammation may terminate, and is prone to develop in a lesion in which the defensive forces of the body have been capable of limiting the acuteness of the infection, but not of overcoming it.

Certain names are applied to inflammatory lesions when they arise in certain tissues in the body. Thus:

A **Catarrhal Inflammation** is one affecting mucous membranes, which in the early stages become dry, vividly red, and the seat of burning or scalding pain, whilst in the later stages there is free secretion of mucus, muco-pus, or pus. At first the secretion of mucin by the hyperæmic membrane wholly or partially ceases, and any extravascular exudate passes into its substance, causing it to become swollen. Cloudy swelling and proliferation of the epithelium follows, with increased formation of mucus and partial or, in severe cases, extensive desquamation of the epithelial cells, these passing into the exudate as catarrhal cells. As the membrane becomes more and more infiltrated with leucocytes, these are added to the discharge, which is thus transformed into muco-pus or even almost pure pus, and ulceration may supervene from the loss of superficial epithelium.

A **Croupous or Plastic Inflammation** is one characterized by the formation of a firm false membrane, due to the coagulation of the plasma exuded from the vessels, and the deposit on the surface such as the pleura, peritoneum, or synovial membrane, gives rise to a layer of plastic lymph, which may be absorbed or organized into fibrous tissue with or without the formation of adhesions. A fibrinous exudate is also seen in the alveoli of the lungs in lobar pneumonia. On mucous surfaces a white, or yellowish-white, flaky mass may be formed—the so-called 'false membrane'—which can be detached, exposing a red and congested surface, with no loss of substance, unless superficial necrosis has also occurred in the mucous membrane itself.

The term **Parenchymatous Inflammation** indicates that, in an inflamed organ or tissue, the process is limited mainly to the actual and active substance of that organ or tissue; whilst in **Interstitial Inflammation** it is confined chiefly to the supporting fibrous tissue.

Clinical Signs of Inflammation.

(A) The **Local Phenomena** may be described under the four headings suggested by Celsus (about A.D. 50), *viz.* 'calor, rubor, tumor, dolor'—heat, redness, swelling, and pain—with the addition of a fifth, *viz.* impairment of function.

Heat.—An inflamed part feels hot to the touch, and the temperature, if taken by a surface thermometer, is definitely raised above that of the surrounding skin. This is due to the increased amount of blood flowing through it, for the temperature of an inflamed area is never higher than that of the blood at the centre of the circulation, *i.e.* in the heart.

Redness is due to the hyperæmic condition of the inflamed part. In the early active hyperæmia the colour is a bright red, fading quickly on pressure, and returning with equal rapidity. During the period of retardation the redness is more dusky, since the blood is longer in passing through the capillaries, and so loses more of its oxygen; the colour does not disappear or return so rapidly, and a slight yellowish tinge often remains from the presence of extravasated hæmoglobin. When stasis is reached, and especially if thrombosis has supervened.

pressure does not remove the red colour, and, should such a state persist for long, permanent pigmentation may remain.

Swelling arises from the same two causes, *viz.* hyperæmia of, and exudation into, the part. Necessarily, the amount of such swelling depends upon the acuteness of the disturbance and the distensibility of the tissue.

Pain results from the mechanical irritation of the peripheral nerve-terminals, both by the increased arterial tension and by the pressure of the exudate, so that it is much greater if, from the density of fascial or fibrous investments, swelling cannot readily occur, *e.g.* in the palm of the hand, or in the eye or testicle. Where the inflammatory products escape into lax tissues, pain is a less prominent symptom, although the swelling may be great.

A marked feature of inflammatory pain is that it is aggravated by pressure, whether intrinsic, *i.e.* by increasing the blood-pressure, as by hanging down an inflamed hand, or extrinsic, from outside agencies, such as mechanical or digital pressure, the pain then being known as tenderness.

The pain of suppuration is throbbing in character; of an inflamed mucous membrane, scalding, burning, or gritty; of an inflamed serous membrane, stabbing; of inflamed bone, aching, or boring, and often worse at night; of an inflamed testicle, sickening. When the organs of special sense are inflamed, there may be little real pain, but much exaggeration of the special sense, *e.g.* flashes of light in retinitis and noises in the ears in otitis interna.

The pain is not necessarily limited to the inflamed part, but is sometimes experienced in distant regions, either owing to participation in the same nerve supply or from the fact that a sensory stimulus is referred by a patient to the end of the affected nerve. For example, in hip disease the chief pain is often felt in the knee, because both joints derive their nerve supply from the same source. In spinal caries pain is frequently experienced in the terminal branches of the nerves issuing from the part affected, *e.g.* the ' girdle ' pain in disease of the dorsal vertebræ, and the so-called ' belly-ache ' when the dorsi-lumbar region is affected. Occasionally a sympathetic pain is experienced on the opposite side of the body, especially when a bilateral organ such as the kidney is involved.

Inflammation of intra-abdominal organs is often accompanied by pain due to tension of the muscular wall of a hollow viscus. Such pain may be definitely local, but is also frequently associated with pain referred to various somatic nerves (viscero-sensory reflexes), and possibly with muscular effects (viscero-motor phenomena). It will suffice here to mention that a renal calculus will produce pain in the groin and front of the thigh (genito-crural area), and perhaps retraction of the testicle; gall-bladder lesions are often productive of pain in the right shoulder. Other illustrations are noted elsewhere.

Impairment or Loss of Function is contributed to by the presence of two or three factors. In most instances inflammatory lesions are accompanied by pain which is accentuated by movement. For this

reason the muscles which control movement in the affected part will develop a protective spasm in order to ensure immobility. This reflex mechanism is best seen in connection with inflammation of joints, and accounts for the classical positions of the limbs which are seen in many disorders of the joints. Sometimes loss of movement is due to the mechanical hindrance produced by the presence of an inflammatory exudate. Thus an orbital cellulitis may produce complete immobility of the eyeball by pressure on the orbital muscles, although the latter may not be the seat of inflammation. In other instances loss of function may be due to the paralyzing effect of the inflammatory process which in infective lesions may result from the direct influence of the toxins on the protoplasm of the cells affected. The best examples of this are found in connection with inflammation of the glandular organs, *e.g.* the liver and kidneys, in which a hepatitis or nephritis is followed by marked impairment and sometimes complete cessation of function.

In **Chronic Inflammation** the symptomatology is relatively subdued. The hyperæmia is less, redness is not so pronounced, heat is not a noticeable feature, and pain is much less acute and is more often of a dull, aching character. Swelling is a more variable feature, and may be slight in amount or very pronounced, and is always more condensed than in the acute variety. Thus, in chronic inflammation of a bone, the cancellous tissue may be completely replaced by sclerosed condensation, which may almost completely occlude the marrow cavity and cause noticeable enlargement of the bone at the same time.

(B) **Constitutional Symptoms** are constantly present in inflammatory conditions, and their severity varies greatly with the cause. In non-bacterial cases there is usually some slight fever which does not last long; but, when bacteria are present, the absorption of toxins may cause general symptoms varying in degree from a mild febrile reaction to a grave toxæmia which causes death. It is, however, remarkable how much disturbance a small collection of pus under tension may sometimes produce.

It is only necessary here to deal briefly with the subject of **Fever** or **Pyrexia.** The general characteristics of the febrile state consist in an elevation of temperature, accompanied by a corresponding acceleration of the rate of the heart-beat and of the respirations. If it continues, the patient loses weight and muscular power. The mouth is dry and the tongue furred; and in the later stages the lips and teeth are usually covered with sordes (accumulations consisting of inspissated mucus and food débris in which bacteria grow and flourish as in a culture-medium). The appetite is impaired, digestion is imperfect, and the bowels constipated; the motions are often very offensive. The urine is scanty and high-coloured, albumen may be present, and, owing to the excessive tissue metabolism, an unusual amount of urea and urates. The skin is often dry.

The intensity and character of the fever vary with the preceding condition of the patient, and with the nature and duration of the disease. In young healthy adults the fever associated with an acute inflammation is usually of an active type, the rise of temperature and

its accompanying phenomena, including, perhaps, a noisy delirium, being well marked (sthenic inflammatory fever). In debilitated subjects, as also towards the close of a long period of pyrexia, *e.g.* in the third week of typhoid fever, and in grave infections, such as erysipelas and septicæmia, exhaustion and collapse manifest themselves (asthenic fever, or the typhoid state). The pyrexia is not necessarily high, and the patient is often only partially conscious, with low muttering delirium, picking at the bedclothes, and passing his excreta in bed.

Treatment of Acute Inflammation.

We shall here deal only with the general principles which may be considered from local and constitutional standpoints.

I. The Local Treatment of Acute Inflammation.

(*a*) **Remove the exciting cause,** if evident and tangible. This may be an embedded foreign body, such as a buried stitch at the bottom of the sinus, or a piece of shrapnel. In other cases it may be possible totally to excise a local focus, *e.g.* the track of infected gunshot wound. In some cases the cause is not evident.

(*b*) **Keep the inflamed part at rest** as far as possible, not only for physical and physiological reasons, but also to prevent mechanical dissemination of the infective agent. This may be effected by confining the patient to bed, or by the use of splints or slings, but special consideration must, at the same time, be given to the possible functional effect which prolonged immobility may have upon a part.

(*c*) **Reduce the local congestion** and promote the removal of the inflammatory exudate which is hampering the efforts of the tissues to regain the mastery over the bacteria. The congestion may be relieved by **elevation** of an inflamed limb, a movement which will aid the emptying of the veins by the help of gravity and also lead to a reflex contraction of the arterioles. The elevation, however, must not be overdone or serious interference with the vitality of the limb may follow. A happy medium must be chosen between the two possible effects, and thus one usually endeavours to assist the venous return without interfering with the arterial supply. **Local blood-letting** by punctures, scarification, and wet and dry cupping is useful in suitable cases and sometimes gives immediate relief from pain.

Cold wisely utilized is of greatest service in reducing hyperæmia by causing contraction of the arterioles. It should be used only in the early stages, as it depresses the vitality of the part, and, if much congestion is present, may do more harm than good. Again, in the case of elderly patients caution is required, as with its injudicious use they may be liable to the occurrence of necrosis of the skin. Cold may be applied by means of an ice-bag; or by irrigation from a vessel containing iced water or lotion, from which strips of lint descend to envelop the inflamed area; or a piece of lint wrung out of evaporating lotion may be placed directly on the part; or, better still, the iced water may be run through a coil of leaden pipes (known as Leiter's tubes), fitted carefully to the inflamed region.

Heat, especially when combined with moisture, is much used in treating inflammation, and acts in a diametrically opposite way to cold by relaxing the vessels and tissues, thus reducing the tension and pain; it also favours the activity and vitality of the part by increasing the vascular supply and facilitating lymphatic absorption. It may be applied in the form of hot fomentations or hot packs or, instead, the method of giving dry heat may be used.

Removal of the exudate may be promoted by free incisions and effective mechanical drainage. Thus, wherever the exudate may collect in spaces in and amongst the tissues, or in an abscess cavity, it is necessary to incise the collection and institute drainage. If the exudate should remain held up in the tissues after incision, its escape may be hastened by applying tissue drainage, and for this purpose the most efficient remedy is the constant application of some hypertonic solution, such as saline (5 per cent.). When the exudate is freely discharging, it must be removed, and this is accomplished by means of suitable dressings and, in some cases, by the use of irrigation or baths.

(*d*) **Increase the supply of healthy blood to the part** by the application of heat or the employment of one of the methods of **artificial hyperæmia.** These measures are of most benefit when the part is not acutely congested, when suppuration has not appeared, and when the condition shows a tendency to become chronic. Artificial or induced hyperæmia, with its accompanying emigration, is useful rather than harmful, if it can be suitably controlled. In acute cases the hyperæmia is usually excessive and, therefore, harmful, as it is the cause of congestion and serves to prevent the excess of fresh healthy blood to the heart.

Induced hyperæmia is of two types, active and passive. The **active** variety consists in determining an increased flow of blood to the part by vaso-dilatation and is, therefore, arterial in origin. This may be accomplished in one of two ways: (*a*) by the application of heat; (*b*) by the employment of counter-irritation. The measures employed for applying heat have already been mentioned. Counter-irritation is based on the principle that stimulation of the sensory nerve supplies will induce a reflex vaso-dilatation deeply in an area which derives its nerve supply from the same source as the sensory branch.

It is applied in many different ways, according to the character of the disease and the part involved. Thus friction with the hand, or with stimulating embrocations, produces a hyperæmic condition of the skin, and promotes local activity in the superficial parts which may react beneficially on deeper structures. Scott's dressing may be similarly employed; it consists in wrapping up the part, *e.g.* a joint, in strips of lint covered with ung. hydrarg. co. (containing over 10 per cent. of camphor), and then encircling it firmly with soap plaster, spread preferably on chamois leather. Iodine paint is another useful application, whilst blisters are most valuable in suitable cases; they are produced by applying a cantharides plaster, or by painting the affected area with liquor epispasticus or a collodion blistering fluid. The actual cautery is the most severe form of counter-irritant, and is

especially useful in some varieties of chronic inflammation of bones and joints. Injection treatment with alcohol, saline, etc., may be used in suitable cases, *e.g.* inflammation of a sensory nerve. Dry cupping is an example of the combined application of heat and counter-irritation.

Passive hyperæmia is venous in nature, and may be induced by the application of a constricting rubber bandage on the proximal side of the inflamed area. It is applied with sufficient firmness to obstruct the venous return without interfering with the arterial supply, and if this is satisfactorily effected, the limb becomes reddish-blue, swollen, and œdematous, but without pain; if it becomes cold, or the patient complains of the pain being increased, the bandage has been applied too tightly. By the use of a blood-pressure armlet and gauge, the amount of pressure may be accurately adjusted. When the correct degree of tension has been reached the limb is comfortable, and the bandage may be retained in position for two or three hours at a stretch twice a day, being removed between the applications so as to relieve the œdema and empty the limb of the accumulated and more or less stagnant blood. This method of treatment is maintained until the inflammation diminishes, and then the length of the daily application of the bandage is gradually reduced.

Klapp's suction balls are employed in cases where a rubber bandage cannot be applied, *e.g.* for an abscess or carbuncle on the trunk or back of the neck, for an inflamed breast, or for a septic finger. A suitably-shaped bell-glass (similar in type to the wet or dry cup of olden days), the edge of which is greased or moistened, is fitted over the inflamed part, and the air within rarefied by a rubber suction-pump. Blood is thereby drawn into the tissues which swell up into the cup; and if there is an open wound, as in a boil or carbuncle, discharge and sloughs are sucked out. The application is maintained for five or ten minutes two or three times a day. Various methods of extracting by suction the exudate from infected tonsillar crypts are also now employed.

(*e*) **Prevent the access of fresh or a mixed infection** to an open wound by suitable dressings and antiseptics.

II. Treatment of Chronic Inflammation.

The principles of treatment which apply in the treatment of acute inflammation are also employed in the chronic variety. In general, it may be stated that the measure adopted will include the removal of the cause and rest to the affected part. In addition, counter-irritation is very useful and may be applied in various ways, as has already been stated. Pressure is an important element in the treatment of chronically inflammatory disorders, and probably acts by improving the tone of the relaxed vessels and by favouring the absorption of inflammatory exudates. Firm bandaging, the use of an elastic support or plaster are the usual methods of application. Artificial hyperæmia also is a useful adjunct, and may be combined with the employment of massage and remedial exercises. In some cases surgical methods may have to be adopted. Finally, general or

constitutional measures must also be considered, particularly in relation to the presence of a chronic inflammation caused by such a disease as syphilis, and vaccines may be prepared and used if the organism can be isolated.

III. **General Treatment.**

This may be considered from the point of view of general measures, drugs, specific therapy, and further surgical measures. General measures consist in the maintenance of complete rest in a well-ventilated room and capable nursing. The diet should be nourishing and ample, but light. The patient should be made as comfortable as possible, and any undue rise of temperature combated by some form of hydrotherapy. Drugs should be used sparingly. They are of value in securing sleep and relieving pain, and may occasionally be of use in reducing the temperature, and for this purpose common antipyretics are the most suitable. At the same time attention should be given to the eliminative functions of the body, and a watch kept for the development of complications such as circulatory failure. Specific therapy will consist in the judicious employment of vaccines and sera, of the use of prontosil in streptococcic infections, and the giving of blood transfusions and, in certain cases, immuno-transfusion. Finally, surgery may be necessary for the evacuation of pyæmic abscesses or other septic complications which may arise.

CHAPTER III.

THE BLOOD IN HEALTH AND DISEASE.

Red Blood-Corpuscles.—In health these vary between 5 and 6 million per cubic millimetre, being slightly more numerous in the male than in the female.

In surgical practice the enumeration of the red corpuscles is of special importance in connection with hæmorrhage. If the blood is examined immediately after a patient has suffered from a severe hæmorrhage, it will naturally be found to be normal in composition; part has been lost, but the quality of the remainder has not yet altered. After a short time the volume of blood is restored to normal by means of fluid absorbed from the tissues. In this stage the blood is more diluted than normal, the red corpuscles and hæmoglobin being alike reduced, the latter more than the former. There is also in most cases a temporary increase in the number of leucocytes. The process of absorption of fluid from the tissues is imitated artificially by the infusion of saline solutions in collapse or after severe hæmorrhage, and it is found that this process has a beneficial effect in accelerating the subsequent regeneration of the blood as well as in raising the blood-pressure and removing the urgent symptoms.

In the subsequent process of recovery the numbers of the red corpuscles increase more rapidly in comparison with the amount of their contained hæmoglobin, so that the colour-index falls. The length of time necessary for full regeneration of the blood varies greatly, the process being more rapid in men than in women, and in young adults than in the old or in children. Approximately 1 per cent. of hæmoglobin is regenerated *per diem*; thus the blood should become normal in about twenty days after the loss of 20 per cent. of hæmoglobin if the patient is kept under favourable conditions.

It is not possible to lay down any definite rule as to the amount of hæmorrhage which is necessarily fatal. Other things being equal, a patient will survive a much greater loss of blood if it takes place gradually than if it takes place quickly. In the latter case a reduction of the hæmoglobin to 50 per cent. will probably be fatal, whereas in the former it may fall to 20 per cent., or even lower, and recovery still take place. Women tolerate loss of blood better than men, and men tolerate it better than children.

Anæmic patients are usually bad subjects for operation, and patients with acute streptococcal lesions very often have a marked degree of anæmia. Opinions differ as to the degree of anæmia which would indicate the advisability of blood transfusions, but in general it may be stated that a fall of the hæmoglobin content of the blood below 50

per cent. is regarded as sufficient indication when a surgical procedure of any gravity is about to be performed.

Leucocytes.—The examination of the leucocytes is often of great importance. It comprises an enumeration of the total number per cubic millimetre, and a differential count of the relative number of the various kinds. In health the blood contains about 8,000 leucocytes per cubic millimetre, five different forms of cell* being present—the polymorphonuclear leucocyte, the eosinophil, the basophil, the lymphocyte, and the large hyaline mononuclear (see Plate III., Figs. 5 and 6).

An increase of the total leucocytes present in the blood is termed **leucocytosis.** Under most circumstances this affects mainly the polymorphonuclears, but sometimes there is an increase of the eosinophils, called **eosinophilia,** or of the lymphocytes, termed **lymphocytosis.** A diminution of the leucocytes is termed **leucopenia.**

Leucocytosis occurs under **physiological** conditions during digestion, after muscular exercise, during pregnancy, and in the new-born infant. This has to be borne in mind in the making and interpretation of leucocyte-counts in disease.

Pathological leucocytosis occurs in many conditions, for example after severe hæmorrhage, and in cachectic conditions, especially in that due to malignant disease, in which it is almost always due to a local inflammation excited by the new growth, and is thus rarely of differential diagnostic value. More important is its occurrence in the majority of the infective diseases, and in these the highest counts are found in **pneumonia** and in **suppuration.** Its occurrence in the latter is of special importance to the surgeon, as the presence of a high leucocytosis may be regarded as the most definite single sign of the presence of pus. It is especially valuable in **appendicitis,** where the other evidences of suppuration are often equivocal, as, when no pus is present, the blood usually shows only a comparatively slight leucocytosis, the number not as a rule exceeding 15,000 per cubic millimetre. When pus is present the number tends to be much greater, being usually not less than 18,000 to 20,000, and may rise as high as 50,000 or even higher. For practical purposes a count of 20,000

* Gulland and Goodall, in their book on 'The Blood' (3rd ed., W. Green and Son, Ltd., Edinburgh, p. 82), and Whitby and Britton in their 'Disorders of the Blood' (Churchill, London, 1935, p. 25), respectively, give the following convenient statements of the proportions of the leucocytes in normal (adult) blood:

Variety of Leucocyte.	*Whitby and Britton.*		*Gulland and Goodall.*
	Total per c.mm.	*Percentage.*	*Percentage.*
Polymorphonuclears	3,000-6,000	60-70	70 } average.
Lymphocytes	1,500-2,700	25-30	20 } average.
Monocytes	350-800	5-10	5 } average.
Eosinophils	150-400	1-4	4 } maximum.
Basophils	0-100	0-1	1 } maximum.

leucocytes per cubic millimetre may be taken as an almost certain proof of suppuration, presuming, of course, that the other causes of leucocytosis can be excluded. Figures between 15,000 and 20,000 may not be absolutely conclusive of the presence of suppuration, and where they are obtained it is advisable to repeat the examination in twenty-four hours or less.

Aleucocytosis and Leucopenia.—The absence of leucocytosis is presumptive evidence that suppuration has not occurred, but several facts have to be considered in applying this rule in actual practice:

1. The cause of the leucocytosis is the passage of the bacterial products from the inflammatory focus to the blood-stream, where they exert a positive chemiotactic action, attracting the leucocytes from the bone-marrow, whilst at the same time they stimulate the latter to an increased production of these cells. As long as the abscess remains unopened and is spreading, these substances gain access to the blood- and lymph-stream with ease. But when the abscess is opened so that the pus laden with bacterial toxins can drain away, the leucocytosis falls, even although the abscess may persist for a time.

2. When the pyogenic bacteria have been killed, the toxins are soon carried away by the circulation and eliminated from the body, and when this has happened the leucocytosis falls, although there may still remain a collection of pus in the tissues. In other words, a high leucocytosis is to be regarded as a proof of the active process of suppuration rather than as a proof of the presence of pus. For example, sterile collections of unabsorbed pus often occur in cases of pyosalpinx of some duration, not necessarily accompanied by leucocytosis, although acute suppuration in the Fallopian tubes causes the usual reaction.

3. When the organisms are virulent and the patient of feeble constitution, so that the infection rapidly spreads, there may be a failure of leucocytosis (aleucocytosis) or even an actual diminution in their number (leucopenia). Such deficiency is found especially in severe cases of diffuse septic peritonitis. The general leucocytosis (as well as the local emigration of leucocytes) must be regarded as a conservative and defensive reaction, and indicates that the patient has sufficient resisting powers to combat the infection, or at least to limit it for a time; the absence of such leucocytosis in a case where there is suppuration renders the prognosis unusually bad.

4. Leucocytosis does not occur in uncomplicated cases of chronic tuberculous or cold abscess. The products of the tubercle bacillus which produces these lesions have no positive chemiotactic action on the polymorph leucocytes, the cells found in the local lesions being mostly of lymphocyte type. We might, therefore, reasonably expect that an increase of the lymphocytes in the blood would occur, but, though a certain degree of this may be found in some cases, it is not often a pronounced phenomenon (see below under 'Lymphocytosis').

Lymphocytosis, or an increase of the lymphocytes, may be absolute or relative. A relative increase (*i.e.* such that the percentage of these cells in the adult rises above, say, 35, although the total number of the leucocytes may not exceed the normal) occurs in tuberculosis and the other diseases mentioned above as giving no leucocytosis. A

great excess of ' lymphocytes ' (100,000 to 260,000 or even more per cubic millimetre) occurs in lymphatic leukæmia.

Mononucleosis is an acute infective disease characterized by enlargement of the lymph-nodes especially of the neck, fever and sore throat, and occurring most frequently in children, sometimes in epidemic form. In some cases there is sore throat, and sometimes the development of ulceration resembling that of Vincent's angina.

Agranulocytosis.—To this condition a variety of names has been applied—granulocytopenia, granulopenia, primary or idiopathic neutropenia—but the term for it at present in most general use is **Agranulocytosis,** or, when the characteristic lesion in the throat often associated with it is present, **Agranulocytic Angina.** As these names imply, the disease is characterized by a diminution, marked, very marked or extreme, or even by a total disappearance, of the finely granular polymorphonuclear cells from the circulation. The hæmopoietic functions of the bone-marrow are three-fold—erythroblastic, leucoblastic, and thrombocytoblastic—for the manufacture of red corpuscles, the granulocytes or marrow-formed granular leucocytes, and the thrombocytes or blood-platelets respectively. By various conditions the output of each of these groups may be increased, diminished or inhibited; and in agranulocytosis there is an inhibition or arrest of the maturation of the granulocytes at the stage of their precursors the myeloblasts, so that, in whole or in part, the ordinary finely granular myelocytes and the polymorphs derived from these cease to be produced, *i.e.* there is an aplasia of these cells without any corresponding aplastic anæmia affecting the red corpuscles or any thrombocytopenia. The disease may follow the toxic action of some infective poison or, as already mentioned, be due to the depressant effect of the drugs of the sulphanilamide group, and in these cases it would appear that there is an undue susceptibility of the bone-marrow to the influence of these poisons.

Eosinophilia, *i.e.* a relative increase of the eosinophils, occurs in several conditions, most of which appear to be due to the action of some ' foreign ' protein.

Blood-Platelets.—These are minute bodies about 2 to 3 μ in diameter, and stain purplish with Leishman's stain. They are formed in the bone-marrow, and are normally present to the extent of 200,000 to 300,000 or more per c.mm. They show a very great tendency to agglutinate upon any damaged areas within the vascular system itself, *e.g.* on diseased heart-valves or upon the damaged lining of blood-vessels; and they also tend to aggregate in clumps as soon as the blood leaves the vessels. They are concerned in the process of coagulation and thrombosis, and are found in very much diminished numbers (thrombocytopenia) in hæmophilia, scurvy, some forms of purpura, and in pernicious anæmia.

The estimation of the **clotting** or **coagulation time** and of the **bleeding time** is often of considerable importance to the surgeon. If the more elaborate and exact methods are not available, the following rough way of testing the **coagulation time** may be employed. The finger or the lobe of the ear is pricked and a drop of blood is transferred to

a slide. A needle is drawn through it from time to time, and the time taken before any fibrin threads adhere to the point of the needle is noted. This corresponds fairly accurately with the clotting time, and is normally between three and five minutes.

The **bleeding time** is roughly estimated by making a small incision in the finger or the lobe of the ear with a three-cornered needle or a small lancet. As the blood collects it is removed with a piece of blotting-paper without squeezing the part or rubbing the surface. Bleeding usually ceases in from three to five minutes.

The Examination of Blood for Bacteria is often necessary, and cultural methods are employed, for their numbers are usually so small that the chance of finding even a single organism in a stained blood-film is remote.

Transfusion of Blood.

Previous to the adoption of a scientific and accurate method of blood grouping, transfusion of blood met with so little success and was attended by so many mishaps that it was laid aside for a time in favour of infusion of saline solution. The modern methods of blood grouping and matching have, however, rendered transfusion comparatively safe.

In cases of serious hæmorrhage and severe shock, transfusion may be given with great benefit. It is also valuable in chronic conditions where much destruction of blood has taken place—*e.g.*, in septic lesions with severe secondary anæmia, in pernicious anæmia and in certain diseases of the spleen; in coal-gas or carbon-monoxide poisoning, and also in cases of hæmophilia and analogous conditions in which coagulation of the blood is deficient. In some cases it is desirable to treat the patient by repeated transfusions of blood before attempting a serious operation.

The chief cause of failure in the past lay in the non-recognition of the fact that the blood of one individual may be incompatible with that of another, and before transfusion is undertaken careful tests must be made to determine this point. The incompatibility may arise in two directions: (1) The red corpuscles of the donor may be agglutinated by antibodies in the serum of the recipient; and (2) such agglutination may or may not be followed by active hæmolysis, the corpuscles being dissolved with a resultant hæmoglobinuria. Hæmolysis is always preceded by agglutination, but does not invariably follow the injection of an incompatible blood; the result depends on the degree of incompatibility. It is necessary, therefore, to find out whether agglutination occurs when the donor's corpuscles are brought into contact with the recipient's plasma.

It has been found that all individuals fall into four main groups as regards agglutination and hæmolysis; this is shown in the table given on page 34. It is probable that there are sub-groups of these, particularly in Group A (or II.) and research is still being done on this important subject, as accidents have occurred even when the donor's group appeared to be suitable. The sera used for grouping must be tested from time to time to prove that they are still active. The

plasma of the donor has generally no appreciable effect upon the cells of the recipient, perhaps owing to its rapid dilution in vessels of the latter, or to the presence of a protective or anti-hæmolytic mechanism in the recipient's plasma. If reference is made to the annexed tables, it will be seen that, as indicated by the absence of agglutination in the *horizontal* row of the table, patients of Group AB (or I.) can safely receive blood from donors of all four groups, and are, therefore, known as 'universal recipients'; whereas members of Group O (or IV.), as shown in the *vertical* column, can give blood safely to a recipient in any of the four groups, and may thus be called 'universal donors.' For further details see below.

The method of testing blood is simple, though the observer must be on his guard against such possible fallacies as the occurrence of auto-agglutination (which does not occur at blood temperature, viz. 37° C.), and pseudo-agglutination or rouleaux formation. The latter can be detected by examination under the low power of the microscope and usually does not take place if the serum has previously been diluted with once or twice its own volume of saline, and if a properly prepared 5 per cent. suspension of the corpuscles has been employed. It is never followed by hæmolysis, and the rouleaux can usually be broken up by tapping the slide smartly. Some sera, especially if used undiluted, may possess the property of inhibiting the agglutination and should not be employed for the test. The red corpuscles of certain patients may be less agglutinable than usual, such feeble agglutination being most liable to occur in direct matching, especially if a weak testing serum is also used. The routine method of procedure is to secure known high titre sera of Groups A (or II.) and B (or III.) which are obtained with aseptic precautions and preserved with 1 per cent. chloroform in small drop bottles or in sealed capillary tubes without any added antiseptic, these being kept in a refrigerator until required, and their potency tested from time to time. A drop of each is placed separately on a slide, and to each is added a small drop of blood (diluted 1 : 20 with saline—*e.g.* in a leucocyte-counting pipette) from the person to be tested, and thoroughly mixed. Clumping of the corpuscles, if it occurs, is usually visible in a few moments and soon becomes well marked. The presence or absence of agglutination may be confirmed by the use of a hand lens or the low power of the microscope.

Even when stock typing sera are available, and the *indirect* grouping of donor's and patient's bloods apparently suitable, the patient's serum and the blood of the prospective donor should always be *directly* tested. A few cubic centimetres of the patient's blood are collected and allowed to clot. A sufficient amount of serum will be available at the end of ten to fifteen minutes—or less if a centrifuge is available. The test is then executed as has been indicated. This test is of particular importance in cases where repeated transfusions are given to the same subject even if the same donor is employed. Recent work indicates that certain antigens, for which there are no natural agglutinins, may be found in the red blood corpuscles. The effect of a first transfusion in these cases might be to produce anti-

Serum of Recipient.	Cells of Donor.				*Relative No. of Individuals in Group.*
	Group AB (or I.).	*Group A (or II.).*	*Group B (or III.).*	*Group O (or IV.).*	
Group AB (or I.)	O	O	O	O	AB (5 per cent.)
Group A (or II.)	×	O	×	O	A (41 per cent.)
Group B (or III.)	×	×	O	O	B (12 per cent.)
Group O (or IV.)	×	×	×	O	O (42 per cent.)

O = No agglutination. × = Agglutination.
(I., II., III., IV. = No. of group according to classification of Moss.)

BLOOD (R.B.Cs.) TO BE TESTED.

Group AB (I.). Group A (II.). Group B (III.). Group O (IV.).

Serum A (II.).

Serum B (III.).

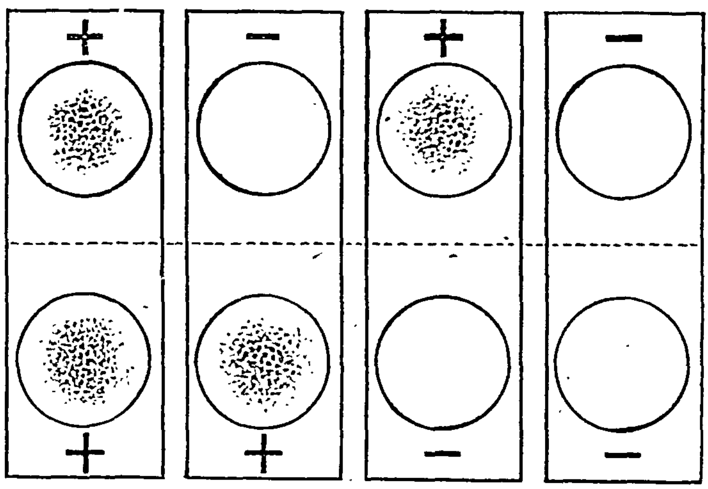


Fig. 13.—Determination of Blood Groups.

These four pairs of reactions correspond with those shown in the two centre horizontal rows in the above table, which indicate why any given pair is sufficient to determine the group of the blood tested.

Group AB can **receive** blood from Groups AB, A, B, and O.
,, A ,, ,, ,, ,, ,, A and O.
,, B ,, ,, ,, ,, ,, B and O.
,, O ,, ,, ,, ,, Group O.

Group AB can **give** blood to Group AB.
,, A ,, ,, ,, ,, Groups AB and A.
,, B ,, ,, ,, ,, ,, AB and B.
,, O ,, ,, ,, ,, ,, AB, A, B and O.

Compare these with the results shown in the *horizontal* and *vertical* rows respectively of the table.

bodies in the recipient's serum which would result in agglutination of the donor's corpuscles in a second or subsequent transfusion. When possible it is best to use blood of a donor of the same group as the patient, but where this is not feasible the blood of a 'universal donor'—*i.e.* of Group O (IV.)—may be given after a preliminary direct matching of the donor's corpuscles with the recipient's serum. If the presence of antigens or antibodies is suspected the direct matching should be done at 0° C., at room temperature, and at 37° C. In hospitals, where transfusion is likely to be required frequently, it is desirable to have certain individuals who may act as donors tested, and their groups determined—a service undertaken in some areas in this country by an association of voluntary donors under the supervision of the British Red Cross Society. Of even greater value is the recent organization of a central 'blood bank' from which stored blood, ready for immediate use, can be issued as required.

Methods of Transfusion.—The success of this procedure depends, not only on the right selection of suitable donors, but also on the technique adopted so as to ensure that no harmful admixture of air or of clot is introduced into the recipient's vessels; it is also desirable that veins should not be harmed so that, if need be, they can be employed again; and that no after-effects are produced. Many different types of procedure have been utilized from time to time, and the following are some of those employed at present.

The technique now much employed is that known as the **Citrate Method,** and is one of the most convenient. The Medical Research Council blood transfusion outfit or some similar apparatus is much used in this country. The M.R.C. apparatus consists of a modified pint milk bottle fitted with an aluminium screw cap lined with a rubber diaphragm. A metal band and a loop are fixed to the base to allow of the bottle being hung up in the inverted position when the blood is administered by gravity. 120 c.c. of anti-coagulant solution, made up of 100 c.c. of 3 per cent. sodium citrate in distilled water and 20 c.c. of 15 per cent. glucose in distilled water, is put in the bottle after sterilization. Because of the danger of caramelization of the glucose the two solutions are sterilized separately and mixed afterwards. 120 c.c. of this anti-coagulant solution is sufficient for 450 c.c. blood. The bottle has a graduated marking at 540 c.c. (Fig. 14.)

Before the withdrawal of blood from the donor the screw cap is removed and replaced by a rubber bung pierced by two glass tubes, each about 3 inches in length. One of these, the air vent, is lightly plugged with cotton wool, and to the other is attached a length of rubber tubing at the end of which is a stainless steel needle protected by a small glass test tube. The bung, tubes and needle are sterilized before use.

The skin of the donor is cleansed with spirit and a sphygmomanometer cuff applied above the elbow. The pressure is raised to 80 mm. of mercury, and this should be maintained throughout the period of venesection. Occasionally, however, the systolic blood pressure of the donor may fall as low as 100 mm. of mercury, particularly in those

who are giving blood for the first time. A watch should, therefore, be kept for this and the pressure of the sphygmomanometer lowered to about 60 mm. of mercury or otherwise the blood flow will cease. A suitable vein, usually in the antecubital fossa, having been selected, the needle is inserted, *bevel downwards,* and the blood allowed to flow *through the rubber tubing into the bottle.* If necessary, suction may be applied to the air vent to increase the flow. An assistant mixes the blood with the citrate solution by gentle agitation. Blood thus obtained may be stored in the refrigerator as described below. In this case the rubber bung is removed from the bottle and the screw cap and diaphragm, which must be kept sterile, are replaced. When possible a Wassermann or Khan test should be carried out before the blood is used.

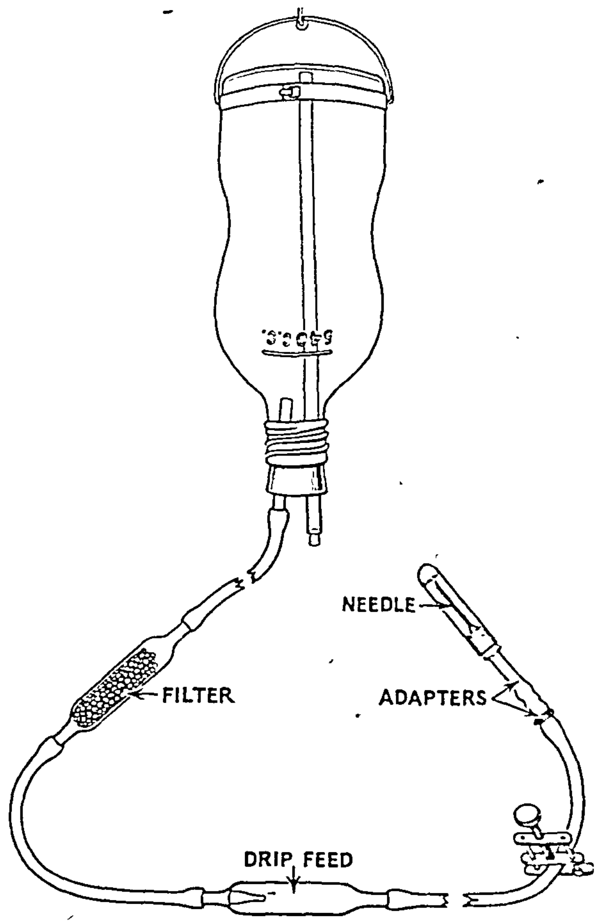


FIG. 14.—MEDICAL RESEARCH COUNCIL'S BLOOD TRANSFUSION OUTFIT.

Before the blood is given to the recipient it should be warmed by standing the bottle in a basin of water at a temperature of 40° C. for fifteen minutes and *gently* rotating at intervals. Another bung, pierced by two glass tubes, is now inserted. One tube, the air inlet, reaches almost to the bottom of the bottle and is closed at its outer end by a small cork. The other tube is 2½ inches in length and is attached externally to a short piece of rubber tubing which is, in turn, attached to an elongated glass bulb containing glass beads (*closed glass-bead filter*). To the other end of the filter is attached a further length of rubber tubing and then, in sequence, a male adaptor, a female adaptor, another short piece of tubing, and a stainless steel needle protected by a small glass test tube. The whole of this delivery apparatus is sterilized before use. A screw clip applied to the rubber tubing below the filter is used to regulate the flow. The bottle is now inverted and hung up at a convenient height, the adaptors are separated and, after a preliminary cleansing of the skin,

the needle is thrust into the vein. When blood appears at the end of the female adaptor the cork is withdrawn from the air inlet, the screw clip is released and blood is allowed to flow from the male adaptor. When the flow is satisfactory the adaptors are joined and blood is allowed to flow from the bottle into the vein. Two other types of filter, the *loose glass-bead filter* and the *gas-mantle filter*, are available for use with this apparatus, and a drip-feed bulb may also be incorporated in the delivery tube if so desired. If the drip-feed bulb is not used it is a wise precaution to insert a glass air-lock tube of greater internal diameter than the delivery tube between the filter and the needle. Blood should generally be given slowly, and approximately thirty minutes taken to introduce the contents of a single bottle. In cases of acute hæmorrhage, however, it may be necessary to introduce a large amount of blood rapidly in order to save the patient's life; but even in such cases the blood should be given slowly for the first few minutes. If it is desired to give more than 450 c.c. of blood, the tube is compressed near the bung, which is then removed from the old bottle and inserted into the new one. The contents of two, four, or even more, bottles may be required for a single case.

In practice it has been found that in some cases unpleasant after-effects such as fever, rigors, and malaise have been experienced with the citrate method, owing, it has been alleged, to the presence of the citrate; but it is more probable that they are caused by bacteria in the distilled water employed or by imperfect cleansing of the tubing or other parts of the apparatus. Fresh triple-distilled water, perfectly pure citrate and glucose, and absolute cleanliness and asepsis are essential for success. Special attention should be paid to the cleansing of the rubber tubing before it is re-sterilized, as small particles of clot may become adherent and may be detached by subsequent use.

Direct Arm-to-Arm Method.—This is carried out by means of the *direct-flow* two-way syringe. Attached to either side of this syringe by rubber tubes are two needles, which are inserted respectively into the veins of donor and recipient. The syringe sucks up blood from the donor, and by turning the grooved piston round to a second position the down stroke of the syringe drives it directly into the vein of the recipient, and this act is repeated as often as necessary. A *direct-flow* three-way syringe, which can be used either for direct or indirect blood transfusion and other purposes, is also obtainable (Fig. 15). The *direct* method is not recommended, as it necessitates the donor and recipient being in close proximity to each other, often an unsuitable position, and, further, it is less simple than the citrate method, and therefore tends to failure more frequently unless carried out by a team of operators who are familiar with this technique.

It should be noted that all needles used for vein puncture should have flat and comparatively short cutting-edged bevels (*not* the long tapering points so often supplied by the makers). They can be sharpened on a fine Arkansas stone, the condition of the bevel being determined with the aid of a hand lens. Coagulation of the blood

within the needles may be prevented by the simple and convenient method of sterilizing and storing them in small glass tubes containing liquid paraffin.

Storage of Blood.

Citrated blood in an M.R.C. bottle or similar container may be stored in the refrigerator and issued when required. Blood should be kept at a steady temperature of between 2° and 6° C. (optimum 4° C.) and should on no account be allowed to freeze. The length of time for which blood can be so kept before use varies according to different authorities; but it is generally held that fourteen or fifteen days should be regarded as the maximum, although blood stored for thirty days or more has been given without ill-effect. A zone of hæmolysis which increases with age usually appears at the surface

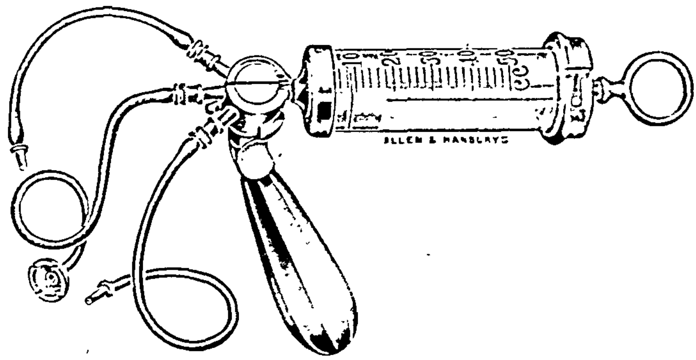


FIG. 15.—'DIRECT FLOW' THREE-WAY SYRINGE FOR BLOOD TRANSFUSION.

of the sedimented corpuscles, and this may possibly be taken as some indication of the state of the blood, although opinion varies on this point. When blood is too old to be used for transfusion the supernatant plasma may be withdrawn, unless there is gross hæmolysis, and used in the preparation of plasma or serum 'pools.'

Transfusion of Blood Plasma and Blood Serum.

The intravenous administration of blood plasma and blood serum instead of whole blood has been found beneficial. This is particularly so in cases of shock, especially the shock attendant upon extensive burns. It has been observed that the hæmoglobin content of the blood can be rapidly reduced to one quarter of its normal value without fatal results; but that reduction of the total volume of the blood to one half its normal value is usually fatal. In surgical shock reduction in blood volume is a marked feature, and the intravenous administration of blood plasma or blood serum provides a rapid and reliable countermeasure.

Liquid Plasma and Serum.

Plasma or serum may be obtained from blood specially drawn for the purpose or it can be extracted from stored blood which is no longer suitable for transfusion. Some controversy has arisen as to the

relative merits of plasma and serum for intravenous transfusion, but results so far are inconclusive and it would seem that there is little to choose between the two. Plasma, however, does not keep so well as serum, as after a time a coagulum, due to the precipitation of fibrin, tends to form. Theoretically, neither plasma nor serum need be subjected to a preliminary agglutination test with the recipient's corpuscles; but it has been found that sometimes agglutinins persist in high titre in stored plasma. For this reason it is desirable to use 'pooled plasma.' Plasma and serum can be stored in the same way as whole blood, but will keep for longer periods.

Dried Plasma and Serum.—This is supplied in 12-oz. 'medical flats' or bottles (Fig. 15A) and can be reconditioned by adding an appropriate amount of distilled water. Each 12-oz. 'medical flat' contains the solids from 200 c.c. of plasma or serum. The reconditioned solution can be given in normal or twice-normal concentration. The advantage of the dried products is that they occupy little space, are readily transported and, being very stable, withstand long storage. The disadvantages are that they are not immediately ready for use, and that a source of distilled water is necessary for their reconditioning. In addition, dried serum is difficult of solution, necessitating further delay.

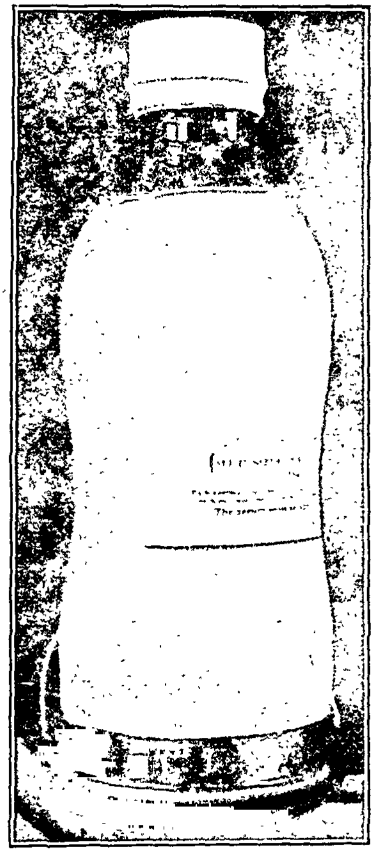


FIG. 15A.—DRIED SERUM.

Venoclysis.

The continuous introduction of normal saline solution, dextrose in saline, citrated blood, blood plasma and blood serum by the 'drip method' has now come into use, and is of great value in a large number of serious conditions, such as septicæmia, uræmia, hyperemesis gravidarum, serious anæmias, due either to deficient hæmopoiesis in the bone-marrow or to excessive loss or destruction of red corpuscles—*e.g.* following upon hæmorrhage from gastric or duodenal ulcers, etc. It may be employed to allay the thirst in late cases of intestinal obstruction, as well as to prepare 'bad surgical risks' before operation and as a safety measure after prolonged or severe operative interference, and in desperate cases generally. This method may also be applied in immuno-transfusion—*i.e.* the use of the blood from cases which have recently recovered from some particular infective condition or have been inoculated against such an infection with the corresponding vaccine. In carrying out this drip method, a small gold-plated Hendon's needle or some special form of glass cannula

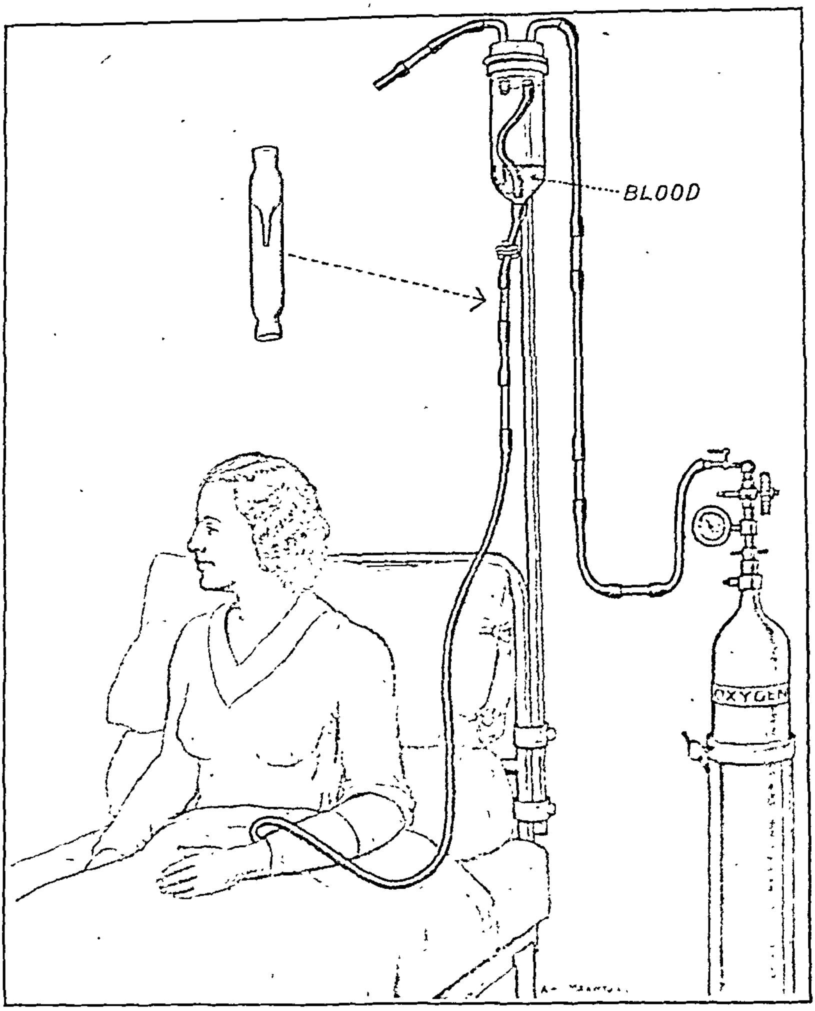
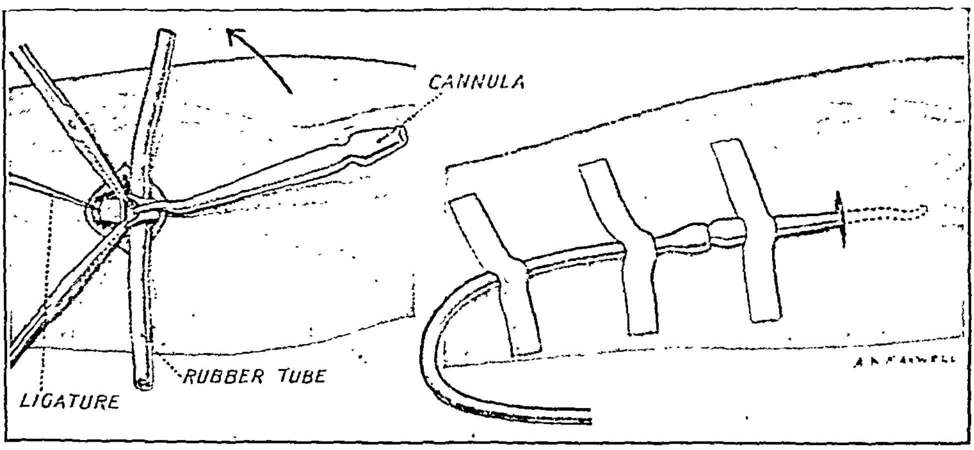


FIG. 16.—CONTINUOUS DRIP BLOOD-TRANSFUSION.

A continuous stream of filtered oxygen is bubbled through the citrated blood in the sterile container to prevent sedimentation of the corpuscles.



17A. 17B.

FIG. 17A.—SHOWING THE VEIN SUPPORTED BY A PIECE OF FINE RUBBER TUBING, WHILST THE DISTAL PORTION OF THE VEIN IS LIGATURED AND THE CANNULA INSERTED INTO ITS PROXIMAL PART.

FIG. 17B.—SHOWING THE CANNULA AND TUBING HELD IN POSITION BY STRIPS OF STRAPPING.

is tied into a vein—*e.g.* the saphenous vein a hand's breadth below the knee, or at the ankle, or, as recommended by Marriott and Kekwick,* who give a full description of this method of transfusion, 'one of the veins in the middle of the forearm at a spot an inch distal to where it joins another vein, and with a valve at the junction which may be tested by emptying the vein from above [Figs. 16, 17A and 17B]. Such a valve is useful in preventing reflux flow into the cannula. The middle of the forearm is most desirable because flexion of the elbow does not then compress the cannula against the vein wall and so obstruct the flow. There is no need for splinting and the patient can flex his elbow as he wishes.' In the lower limb immobility may be secured by the use of a suitable splint, and care should be taken to ensure the use of a cradle as the weight of bedclothes on the thigh might tend to obstruct the saphenous vein. The Hendon's needle after introduction may be stitched in place to the skin, or, if a glass cannula is used, it and the adjacent portion of the attached rubber tubing may be strapped in position with adhesive tape. The solution to be introduced by this method may be placed in a large glass container which is suspended at the head or side of the bed.

The most suitable rate is forty drops to the minute. If blood is being administered, oxygen should be bubbled through continuously to prevent sedimentation of the corpuscles. The rate of flow of the oxygen should be roughly forty bubbles per minute. The blood is filtered through nickel wire gauze at the bottom of the bottle. Saline or glucose may be administered in the same way, and if run in at the rate mentioned above there is no need whatever to warm these solutions. Too much glucose should not be run in as it tends to cause thrombosis in the vein.

In cases where several blood transfusions are to be administered to the same patient, a special double dripper should be used. This will allow blood and saline to be given together or separately, and this is of special value when the blood supply becomes exhausted before a second donor has been obtained. In this case the saline solution can be run in; thereby the vein and apparatus are kept patent until more blood is available.

* 'Continuous Drip Blood-Transfusion,' H. L. Marriott and A. Kekwick, *Lancet*, April 27, 1935, p. 977.

CHAPTER IV.

PYOGENIC INFECTIONS AND INFECTED WOUNDS.

In this chapter we propose to deal with a series of affections associated with or allied to suppuration, and due to organisms, usually termed **pyogenic,** which cause an inflammatory reaction in the tissues, sooner or later associated with liquefaction of both tissue and exudate, the liquefied material being known as **pus,** and the process which leads to its formation as **suppuration.** Any localized collection of pus in the tissues is known as an **abscess,** and this may be acute or chronic. Sometimes the infection involves the cellular tissue of a part in a more or less diffuse manner, the pus infiltrating widely, this condition being termed **cellulitis;** or it may implicate a serous cavity such as the pleura or peritoneum. Constitutional phenomena are associated with these local manifestations, and may be of two types: (*a*) When toxic products alone are absorbed, resulting in **toxæmia** or some modification of the same; and (*b*) when the bacteria invade the blood-stream and become disseminated to distant parts, thereby giving rise either to **septicæmia** or to **pyæmia.** Varying degrees of these three processes may occur in combination in any given case.

Bacteriology.—The more important pyogenic bacteria* are:

The Staphylococci.
The Streptococci.
The Pneumococci.
The Bacillus coli (*or Bacterium coli*) Group.
The Typhoid-Paratyphoid Group.
The Bacillus Pyocyaneus (*pseudomonas pyocyanea*).
The Proteus Group.
The Gonococcus (*Neisseria gonorrhœæ*).

(1) **Staphylococci** (*Staphylococcus aureus, citreus,* and *albus*) (Plate I., Fig. 1) are very widely distributed, being common in air, dust, etc. They are constantly found in or on the human skin, and suppurative inflammations of it and of the subcutaneous tissue are very frequently due to them; and even when the inflammation is caused by other organisms in the first instance a secondary infection with staphylococci almost always takes place later. Impetigo contagiosa, a disease due primarily to streptococci, may be taken as one example of this, and

* For the microscopical and cultural characters of such micro-organisms textbooks of Bacteriology should be consulted. The recent nomenclature has been included in brackets.

PLATE I.

FIG. 1.—FILM OF PUS CONTAINING STAPHYLOCOCCI, SHOWING THE GRAM-POSITIVE COCCI IN TYPICAL BUNCHES.

A small mononuclear cell contains the remains of an ingested pus-cell. (Gram's Stain, ×1000.)

FIG. 2.—FILM OF PUS, SHOWING SHORT CHAINS OF STREPTOCOCCUS PYOGENES FOR COMPARISON WITH FIG. I.

A few cocci have been englobed within the cells. (Gram's Stain, ×1000.)

FIG. 3.—FILM OF SPUTUM, SHOWING MIXED INFECTION WITH GRAM-POSITIVE PNEUMOCOCCI, AND GRAM-NEGATIVE FRIEDLÄNDER'S PNEUMOBACILLUS (*Encapsulatus pneumoniæ*) (LARGER) AND *Hæmophilus influenzæ* (PFEIFFER'S B. INFLUENZÆ) (SMALLER BACILLI).

(Gram's Stain, ×1000.)

FIG. 4.—FILM OF EMPYEMA PUS, SHOWING A PURE INFECTION WITH *Streptococcus pneumoniæ* (PNEUMOCOCCI), WITH THEIR CAPSULES STAINED.

The endothelial cell contains englobed carbon pigment. (Rd. Muir's Capsule Stain, ×1000.)

FIG. 5.—FILM OF GONORRHŒAL PUS.

Two of the pus-cells are crowded with Gram-negative *Neisseria gonorrhœæ* (gonococci), a few of which are also free, along with some Gram-positive staphylococci. (Gram's Stain, ×1000.)

FIG. 6.—ANOTHER FILM OF GONORRHŒAL URETHRAL DISCHARGE, SHOWING A PURE GONOCOCCAL INFECTION.

The cytoplasm of two pus-cells is crowded with gonococci, and an epithelial cell contains two pairs. (Leishman's Stain, ×1000.)

FIG. 7.—DIPHTHERIA BACILLI (*Corynebacterium diphtheriæ*).

Film from young blood-serum culture, showing typical metachromatic granules. (Neisser's Stain, ×1000.)

FIG. 8.—PSEUDO-DIPHTHERIA BACILLI (*Corynebacterium hofmanni*).

Film from young blood-serum culture, showing 'barring,' but absence of metachromatic granules. (Acid Toluidin Blue Stain, ×1000.)

FIG. 9.—FILM FROM VINCENT'S FUSI-SPIROCHÆTAL INFECTION (TONSIL), SHOWING THE TYPICAL FUSIFORM BACILLI AND SPIROCHÆTES.

A couple of surface squamous epithelial cells and a pus-cell are also shown. (Leishman's Stain, ×1000.)

PLATE I.

Fig. 1.—Film of Pus containing Staphylococci, showing the Gram-Positive Cocci in Typical Bunches.

A small mononuclear cell contains the remains of an ingested pus-cell. (Gram's Stain, ×1000.)

Fig. 2.—Film of Pus, showing Short Chains of Streptococcus Pyogenes for Comparison with Fig. 1.

A few cocci have been englobed within the cells. (Gram's Stain, ×1000.)

Fig. 3.—Film of Sputum, showing Mixed Infection with Gram-Positive Pneumococci, and Gram-Negative Friedländer's Pneumobacillus (*Encapsulatus pneumoniæ*) (Larger) and *Hæmophilus influenzæ* (Pfeiffer's B. influenzæ) (Smaller Bacilli).

(Gram's Stain, ×1000.)

Fig. 4.—Film of Empyema Pus, showing a Pure Infection with *Streptococcus pneumoniæ* (Pneumococci), with their Capsules Stained.

The endothelial cell contains englobed carbon pigment. (Rd. Muir's Capsule Stain, ×1000.)

Fig. 5.—Film of Gonorrhœal Pus.

Two of the pus-cells are crowded with Gram-negative *Neisseria gonorrhœæ* (gonococci), a few of which are also free, along with some Gram-positive staphylococci. (Gram's Stain, ×1000.)

Fig. 6.—Another Film of Gonorrhœal Urethral Discharge, showing a Pure Gonococcal Infection.

The cytoplasm of two pus-cells is crowded with gonococci, and an epithelial cell contains two pairs. (Leishman's Stain, ×1000.)

Fig. 7.—Diphtheria Bacilli (*Corynebacterium diphtheriæ*).

Film from young blood-serum culture, showing typical metachromatic granules. (Neisser's Stain, ×1000.)

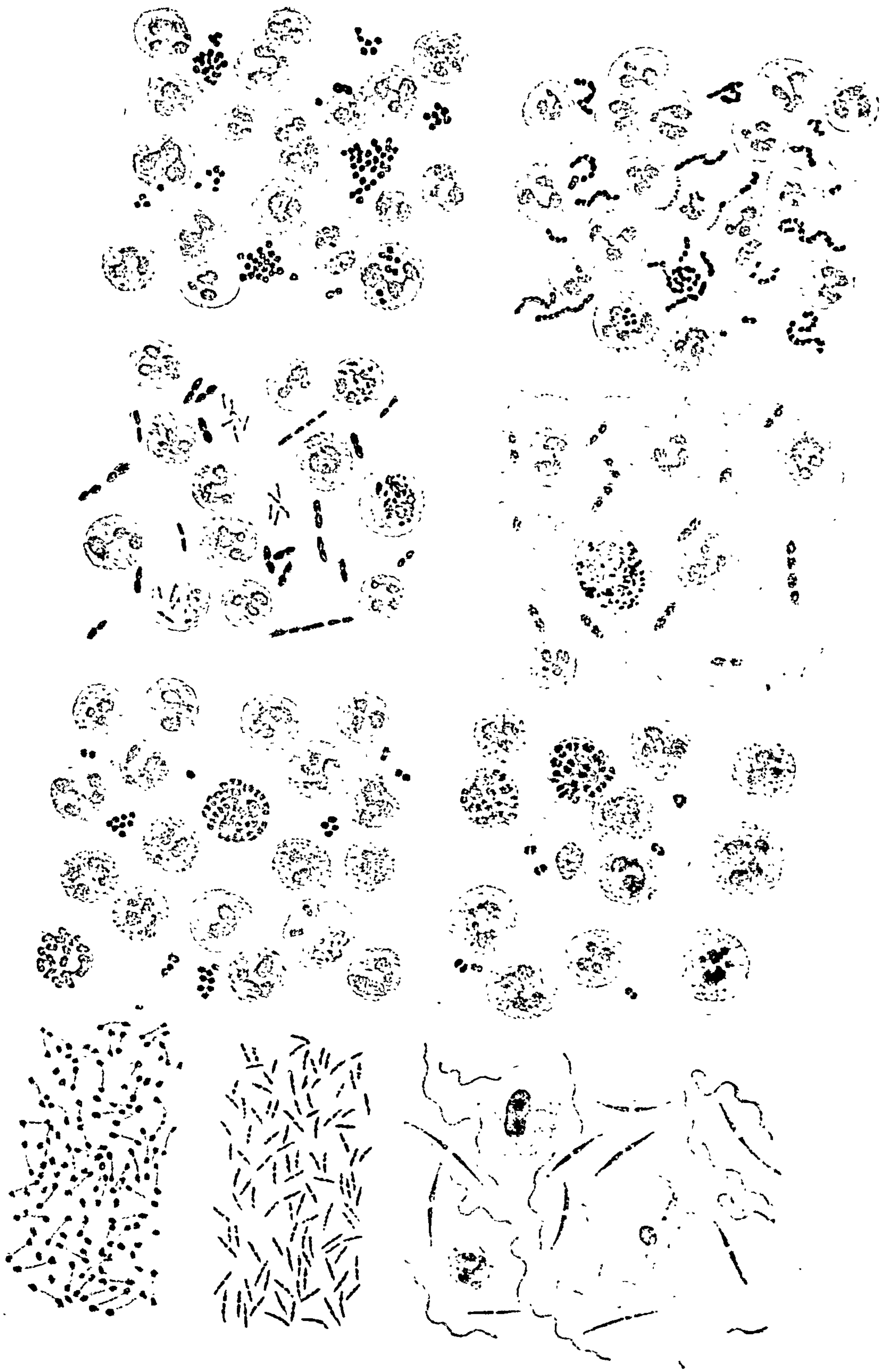
Fig. 8.—Pseudo-diphtheria Bacilli (*Corynebacterium hofmanni*).

Film from young blood-serum culture, showing 'barring,' absence of metachromatic granules. (Acid Toluidin Blue Stain, ×1000.)

Fig. 9.—Film from Vincent's Fusi-Spirochætal Infection (Tonsil), showing the Typical Fusiform Bacilli and Spirochætes.

A couple of surface squamous epithelial cells and a pus-cell are also shown. (Leishman's Stain, ×1000.)

PLATE I



the vesicles of small-pox and vaccinia as another, for in each case a secondary staphylococcal invasion takes place. The chief lesions of the skin and subcutaneous tissues due to staphylococci are abscesses, boils, carbuncles, pustular acne, etc. In some cases diffuse spreading cellulitis may be produced by them, but this is unusual. Deep-seated suppuration, such as periostitis and osteomyelitis, perinephric abscess, empyema, etc., may also be due to staphylococci; in fact, they may cause suppuration in any part of the body. Lastly, staphylococcal septicæmia, pyæmia, and ulcerative endocarditis occur, but are less common than the forms due to streptococci, and the prognosis is slightly less grave.

Cases of post-operative suppuration, particularly stitch-abscesses in the skin, in which antiseptic or aseptic precautions have failed, are practically always due to staphylococci, either alone or in admixture with other organisms.

(2) **Streptococci** (Plate I., Fig. 2).—Streptococci form a heterogeneous group containing numerous different types or species, and it is also recognized that the *same* strain of streptococcus may at different times show all degrees of pathogenicity, and may, *e.g.* on passage through a series of susceptible persons or animals, become progressively more and more virulent, as the surgeon and pathologist sometimes learn to their cost when they prick or cut their fingers whilst operating upon cases of streptococcal infection; whereas, on the other hand, such virulence may be diminished or may practically vanish when the organism is passed through a succession of subcultures outside the body.

Streptococci grow in longer or shorter chains; but any classification according to length of chain, whether *in vivo* or *in vitro*, is of comparatively little value, as this may vary even in the same strain, not merely with the type under investigation, but also with the culture medium. They are mostly aërobic and facultatively anaërobic, but some anaërobic varieties also occur.

Of the hæmolytic streptococci, *Streptococcus pyogenes* is the commonest and most important. Closely allied to or possibly identical with it is the streptococcus of erysipelas. The serological classification of streptococci by specific agglutinating sera and absorption tests is as yet too complex and uncertain a proceeding for ordinary routine clinical use.

The lesions produced depend upon the virulence of the organism and the varying susceptibility or resistance of the patient, and may include localized abscesses, spreading forms of suppuration such as erysipelas and cellulitis, lymphangitis, lymphadenitis, etc.; whilst still more fatal streptococcal affections are meningitis, septicæmia and pyæmia, puerperal fever and ulcerative endocarditis.

The discovery that the dark red synthetic azo-dye known as 'prontosil' when administered by the mouth has a distinct protective and curative action against virulent hæmolytic streptococci is a notable advance in chemotherapy. The closely allied dye 'prontosil solubile' may also be administered intramuscularly, and it has further been found that this specific protective action is due to the colourless parent

substance* (which has been given the shortened name of **Sulphonamide-P**) into which these dyes are broken up in the animal body. This latter substance itself may, therefore, be administered in tablet form† by the mouth, or when this is not possible it may be tried intramuscularly, *not* intravenously, as its injection directly into the circulating blood has been followed by undesirable toxic reactions. Its clinical use in the human subject has followed the successful experimental protection of mice‡ by it against virulent strains of *Streptococcus pyogenes*, and perhaps also, though in lesser degree, against meningococci.

More recent variations of this drug are now efficacious against the pneumococci or meningococci, and success has also been obtained in connection with erysipelas, scarlet fever, acute streptococcal tonsillitis, and gonorrhœa.

Any number from six to ten 0·5-gramme tabloids may be administered daily by the mouth and continued for about a week after the temperature has fallen to normal. If it should not be tolerated by the stomach (the simultaneous internal use of magnesium sulphate should be avoided) its intramuscular injection may be tried. The occurrence of sulphæmoglobinæmia may constitute a contra-indication to this line of treatment.

Non-hæmolytic varieties of streptococci may produce lesions which tend to be less acute than the foregoing. Of these, *Str. salivarius* and *Str. mitis* are common inhabitants of the mouth, throat, etc., and may acquire a varying and sometimes considerable degree of pathogenicity, being very frequently associated with infections of the teeth and gums, tonsils, nasal sinuses, middle ear, etc., and with lesions elsewhere secondary to these, such as in the gall-bladder, appendix, renal pelvis, etc., and such focal infections are not unfrequently found in cases of rheumatism. From their tendency to produce in culture a greenish discoloration of hæmoglobin, a somewhat heterogeneous group of these non-hæmolytic streptococci have, rather loosely, been termed '*Str. viridans.*'

'*Str. fæcalis,*' also non-hæmolytic, probably comprises a group of closely allied species. It is a normal inhabitant of the intestine, which occurs very commonly in wounds contaminated with fæcal material, and is an organism usually of only moderate virulence.

(3) **The Pneumococcus** (Streptococcus pneumoniæ) (Plate I., Fig. 4) is practically a normal inhabitant of the mouth. It is the commonest cause of acute lobar pneumonia and the accompanying pleurisy. Four main serological types are described, of which Types I. and II. are found especially in acute lobar pneumonia. Infections with these two types, more especially Type I., and also, but to a lesser degree, with Type II., but not the others, are often benefited by the use of the homologous serum and the mortality considerably reduced. The pneumococcus is found in many suppurative conditions connected

* *p*-aminobenzenesulphonamide.

† 'Tabloid' Sulphonamide-P.

‡ See articles by the Staff of the Wellcome Research Laboratories in *The Lancet*, 1936, i., 1286, and *ibid.*, 1937, i., 16, etc.

with the lungs, especially empyema, and often as a secondary infection in other pulmonary lesions; thus, in the walls of a tuberculous cavity suppuration is very frequently due to pneumococci alone or in conjunction with other organisms. It is a common cause of nasal sinus infection and middle-ear disease, and of their cranial or intracranial complications. Pneumococci also cause arthritis, which may or may not result in suppuration, and may follow an attack of pneumonia. Peritonitis also may be due to this organism, especially in young children, and may be primary, or secondary to some pulmonary lesion. In pneumonia, especially in the more serious cases, as well as in grave pneumococcal infections elsewhere, the pneumococcus frequently enters the blood in varying numbers and may sometimes produce a definite septicæmia, with or without ulcerative endocarditis.

(4) **The Bacillus coli** (Bacterium coli) **group** (Plate III., Fig. 4) occurs in great numbers in the contents of the healthy intestine. It is distinguished from the typhoid-paratyphoid-dysentery group by the serological reactions of these and by its action on various sugars, especially its fermentation of lactose, the latter group being non-lactose fermenters.

Under normal conditions the bacilli of the *Bact. coli* group, which occur in the intestinal contents, are not very virulent, but when any pathological condition arises in the gut, and the resistance of this is lowered, *e.g.* strangulation, ulceration, perforation, etc., active invasion of the tissues by it, usually along with other organisms, especially streptococci, **Clostridium welchii** (or bacillus welchii), etc., may follow, and may lead to appendicitis, acute peritonitis, etc., any pus so formed having usually a fæcal odour. *Bact. coli* and its allies may also give rise to cholecystitis and cholangitis. It is one of the commonest causes of pyelitis and pyelocystitis, in which it is frequently associated with streptococci.

(5) **The Typhoid-Paratyphoid Group.**—*Bacterium typhosum* (bacillus typhosus) and its relatives of the paratyphoid group sometimes cause abscesses, especially in connection with bones or joints, after an attack of the specific fever. It is now well known that for many years after such an attack some persons continue to excrete these bacilli in the urine or fæces, in the latter instance the commonest focus of such persisting residual infection being the gall-bladder. These typhoid and paratyphoid 'carriers,' as they are termed, may at any time initiate an epidemic of the disease.

(6) **Bacillus pyocyaneus** (pseudomonas pyocyanea) is occasionally a cause of suppuration, *e.g.* in the middle ear, or in gunshot wounds, etc. The pus produced by it turns bluish-green when collected on dressings and exposed to the air. The discharge is often abundant, and has a characteristic musty smell. The infection is not as a rule of grave import, and may usually be controlled by suitable drainage and antiseptics without much difficulty. This organism, however, sometimes gives rise to a general infection somewhat resembling typhoid fever, and it may then be found in the blood, fæces, and urine.

(7) **The Proteus Group.**—*Proteus vulgaris* (bacillus proteus) and some

of its allies are a not uncommon cause of suppurative cystitis and otitis.

(8) **Gonococcus** (Neisseria gonorrhœæ) (see p. 133).

Many cases of suppuration are due to a **mixed infection** with two or more of the species of bacteria enumerated above, or with some of the anaërobes described elsewhere. In other instances an abscess formed by the action of one of the pyogenic bacteria may be subsequently infected with simple saprophytes which have the power of growing in pus and dead tissues, but do not as a rule invade the living tissues. This is especially liable to occur in a large abscess when the drainage is insufficient, or when the dressing is not performed with sufficient care as to asepsis. Such an accident should be studiously avoided, for lesions due to a mixed infection heal with difficulty, the tissues appearing more easily to acquire immunity against a single variety of organism than against two or more at the same time. The fact that a wound is already infected is no reason for neglecting to treat it with the fullest aseptic precautions, and this should also be borne in mind in connection with operations on the mouth, rectum, etc.

I. Acute Abscess.

Ætiology.—It may be taken as established that suppuration as met with in surgical practice is almost always due to the action of bacteria, though occasionally it may follow upon the intramuscular or other injection of certain medicaments.

Bacteria can reach the area, which becomes inflamed either from outside the body or from within. Staphylococci are commonly present in the skin, and often on instruments, sutures, dressings, etc., and it is to infection from such external sources that most cases of post-operative suppuration are due. Suppuration and abscess formation is particularly liable to occur in lymph-nodes, from the spread of infection in their drainage areas, *e.g.* in the axillary nodes from the fingers, etc., or in the cervical nodes from the tonsils, teeth, etc.

In some cases, however, bacteria gain access to the tissues by way of the blood; thus a deep lesion (such as a ruptured muscle or ligament) may result in suppuration, although the skin over it is unbroken, and the intervening tissues are apparently healthy. Here we must assume the existence of auto-infection (p. 4), the bacteria reaching the blood from some pre-existing septic focus elsewhere, such as infected gums, teeth, tonsils, nasal sinuses, intestine, especially the appendix, etc.

In other cases abscesses may be due to organisms which have lain latent in the tissues locally, it may be, for long periods. The possibility of this, especially as a sequel in wounds of ragged and irregular shape which have been the seat of prolonged suppuration, has already been mentioned (p. 5), and it is a factor that has to be carefully considered in deciding upon the best time to perform secondary plastic or other operations, *e.g.* on bones or nerves; usually it is wise to wait for from three to six months, special attention being given meanwhile to the patient's general health. Bruising of the part without breach

of surface, or opening up the parts again by an operation, or even serious depreciation of the general health without any wound, may suffice to light up active suppuration once again. Another example may be seen in the bone abscesses which sometimes develop months or years after an attack of typhoid fever, and are due to the typhoid bacillus, though in this case we cannot always exclude the possibility of a subsequent reinfection, or of the patient's being a 'carrier.'

Pyæmic or secondary embolic abscesses, due to the breaking down and diffusion of infected blood-clot in a thrombosed vein or of vegetations on a heart-valve, are described on p. 75 *et seq.*

Uninfected foreign bodies, *e.g.* silver wire or glass splinters, do not produce suppuration, except in the rarest of cases by auto-infection. This fact is constantly utilized in surgical practice; deep layers of the tissues are brought together by carefully sterilized buried sutures, and divided structures such as bones, ligaments, etc., can be approximated and held in position by wire, screws, pegs, or other buried appliances, which would cause serious trouble but for their complete sterilization.

Formation and Structure of an Acute Abscess.—The bacteria which have gained access to the tissues multiply and produce toxins which are diffused into the surrounding structures, giving rise to acute inflammation; the vessels dilate, acceleration of the blood-stream occurs, followed by retardation and thrombosis, and by migration of leucocytes. More vigorous action of the toxins on the injured tissues destroys their vitality, usually by a process of coagulation necrosis. A microscopical section through the lesion at this stage will show two well-differentiated zones: a central area in which the tissues are dead, have lost their staining properties, and contain the pyogenic bacteria; and a peripheral zone of acute inflammation, which fades gradually into the surrounding healthy tissues. This inflamed zone is thickly infiltrated with leucocytes, mainly of the polymorphonuclear variety, since the products of pyogenic bacteria have special attractive (chemiotactic) powers for this form of leucocyte.

The central necrotic mass which contains the bacteria is at this stage still attached to the surrounding living tissues, and if the lesion is incised it will appear as a slough, which can be removed only with difficulty. But this condition soon changes; as a result of increasing exudation, especially of plasma, the tension in the inflammatory focus becomes so great that the cohesion of the tissues around the central slough is destroyed; and a third zone—of polymorph leucocytes in fluid—is formed between it and the inflamed outer zone.

The fate of the slough varies according to circumstances. It may be recognized when an abscess is opened, *e.g.* as the core of a boil, or, if not too large, it may be in part absorbed by the leucocytes and in part digested by the enzymes formed by many pyogenic bacteria and from dead and disintegrating leucocytes. Or it may happen that no definite slough is formed, the earliest effect of the bacteria being to attract the leucocytes in great numbers into inflamed but still living tissues—a process of purulent infiltration rather than of abscess formation.

An abscess, then, consists of a collection of leucocytes suspended in fluid and surrounded by a zone of inflamed tissue (Fig. 18). The leucocytes, disintegrated tissue, and fluid are collectively termed **pus,** and the characteristic cells of the pus from an acute abscess are the polymorphonuclear leucocytes, then known as pus-cells. Many of these are dead, having been killed by the toxins (as can be seen from their loss of motion when the pus is examined on a warm stage, and by their staining reactions), and others undergo various degenerative changes, especially fragmentation of their nuclei. Some of them may contain bacteria.

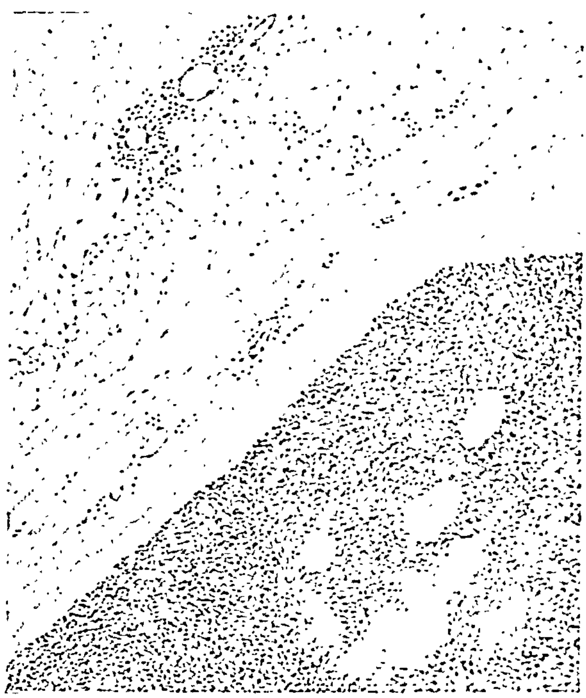


FIG. 18.—FORMATION OF ABSCESS IN MUSCLE AT FORTY-EIGHT HOURS.

The pus-cells of the abscess are seen in the lower part, which also contains some fragments of necrosed muscle. The band of muscle passing diagonally across the figure, and the fatty areolar tissue above it, show some inflammatory œdema and infiltration with leucocytes.

At first the abscess may extend rapidly, but after a day or two (in most cases) a certain amount of local immunity is produced, and the abscess spreads more slowly. This is an indication of the fact that the tissues, which were at first overwhelmed by the action of the bacteria and their toxins, are now carrying on the contest on more even terms. At this period the cavity becomes lined by **granulation tissue** (Fig. 19), which forms a thick, soft layer of velvety appearance and bright pink colour. It is composed of large numbers of loops of newly-formed blood-vessels, leucocytes, and tissue-cells in a state of active proliferation. Its development does not necessarily indicate that the abscess has entirely ceased to spread, for the toxins may still be powerful enough to kill the delicate newly-formed tissue; but in most cases its appearance is the first indication of repair and of the ultimate victory of the tissues. Leucocytes continue to pass from these newly-formed thin-walled vessels into the abscess cavity, being attracted chemiotactically by the substances present in the pus; hence the layer of granulation tissue appears to 'secrete' pus, and was formerly called a 'pyogenic membrane.' Its formation was anxiously looked for in the days when suppuration was considered essential in the healing of the wounds, since it opposes a barrier to the absorption of bacteria and their toxins. Thus the formation of thick, creamy pus

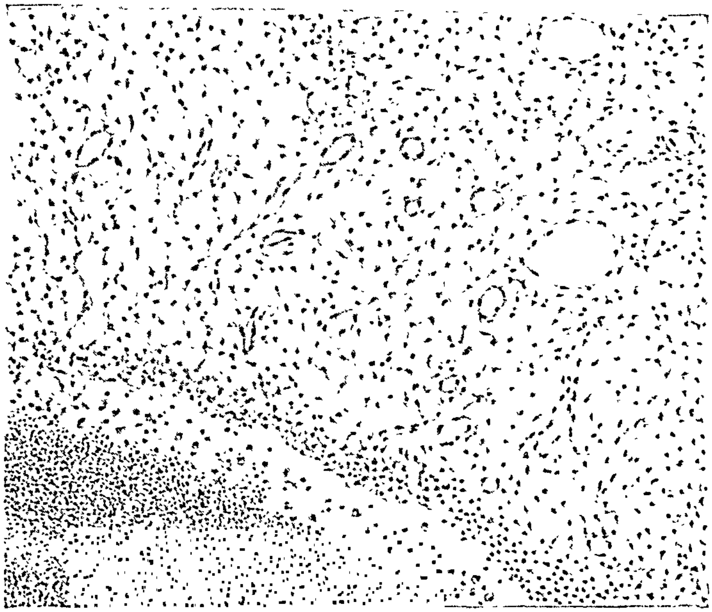


FIG. 19.—RESOLVING ABSCESS AT FOUR DAYS.
Early vascularization and formation of young granulation tissue.

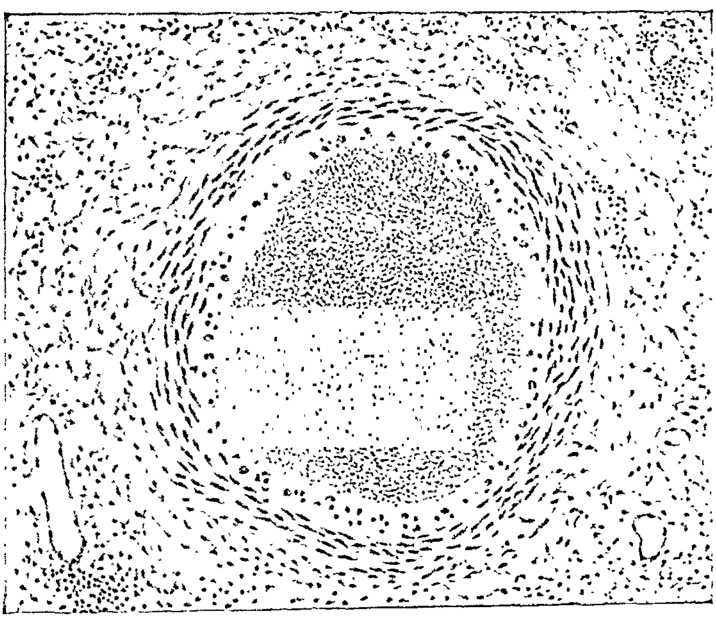


FIG. 20.—RESOLVING ABSCESS AT EIGHT DAYS.
The central pus is undergoing absorption and is surrounded by a layer of young fibroblasts. Compare with Fig. 19 above.

of a yellowish colour was considered a sign that the patient was practically out of danger of 'blood-poisoning,' and the pus was termed 'laudable.'

Abscesses may not spread equally in all directions, since certain structures, especially bone and fascia, are more resistant than cellular tissue or fat. The process of extension tends to continue along the line of least resistance, *e.g.* along muscular and fascial planes, until the abscess 'points' at some surface, and finally bursts through the skin or into the alimentary canal or other cavity. The actual bursting of an abscess is often due to some injury—it may be a slight one—usually preceded by superficial ulceration or necrosis. When the pus and the contained bacteria and their toxins are able to escape externally, the erosive action of the pyogenic membrane becomes less profound, and the contest between the defensive powers of the tissues and the destructive powers of the bacteria, in which the latter were at first victorious, turns in favour of the tissues. The bacteria which remain are attacked with greater effect by the leucocytes, and are gradually removed; the production of toxin diminishes; the inflammatory process ceases, and finally organization of the granulation tissue commences. This begins at the deepest part of the abscess cavity, the walls being kept apart from one another by the pus which is still being formed, though in gradually diminishing quantity, and the process is facilitated if efficient drainage is provided.

Occasionally the defensive powers of the body are sufficient to kill off the bacteria after pus has been formed, and before it has escaped. When this happens, the pus may become absorbed and the cavity obliterated, or the fluid part only may be absorbed, and the leucocytes and débris (which undergo fatty degeneration) remain as a cheesy, structureless mass, a varying degree of calcification perhaps ultimately supervening. In either case the abscess wall organizes into fibrous tissue, constituting a deep scar, in the centre of which may be the inspissated pus. This rarely happens, except in the abdomen, and then usually in connection with the appendix, Fallopian tube, or liver. In a few cases bacteria may remain enclosed in the newly-formed connective tissue and persist in a latent condition, but still capable of again developing pathogenic activity.

The Clinical Signs and Symptoms of an acute abscess may be described under three headings:

1. **The local signs** consist of a patch of inflamed tissue, indicated by heat, pain and tenderness, redness, and swelling—such swelling being at first hard and brawny, but when pus forms the centre becomes soft and elastic, whilst superficial œdema is more marked. The intensity of the pain, which is throbbing in character, depends upon the density of the tissue affected and the supply of sensory nerves to the part, suppuration beneath a resisting membrane, such as the palmar fascia, being always intensely painful. **Fluctuation** is the most characteristic sign of the presence of fluid; it is obtained by making firm pressure with the finger or fingers of one hand on one part of the swelling, whilst the fingers of the other hand placed on another part receive the impulse transmitted across the intervening space in the

form of a fluid wave. Some soft solids give a sensation of fluctuation, *e.g.* lipomas, and soft rapidly-growing sarcomas; whilst, on the contrary, it may be absent when the fluid is under great tension, or surrounded by a thick wall, or widely diffused in such a structure as the glandular tissue of the breast.

Sometimes, when the pus is small in quantity, all that can be detected is a feeling of elastic resistance in the centre of the brawny hyperæmic mass; but this, to the practised finger, is quite as conclusive of the presence of fluid as fluctuation. When the pus is placed deeply under muscular and fascial planes, very careful examination may be needed in order to determine its presence; the surgeon must not be misled by the sense of fluctuation obtained *across* the fibres of a muscle; but, in the absence of pus, such fluctuation will not be felt on palpation in the longitudinal axes of the muscle-fibres. Marked and increasing œdema is frequently conclusive of the presence of deeply-seated pus, *e.g.* in acute osteomyelitis and suppurating mastitis.

2. **Pressure effects** are due mainly to the mechanical influence of the swelling upon surrounding structures. The most evident are those due to the irritation of nerves, as a result of which neuralgic pain may be present, or the patient may refer the pain to some distant unaffected region. In some cases, where large blood-vessels traverse the suppurating focus, the tissues surrounding them may be destroyed, leaving them exposed in the abscess cavity as bands. Thrombosis and subsequent obliteration may result, especially in the veins; or occasionally hæmorrhage follows, due to erosion of the vessel wall (suppurative periarteritis or periphlebitis), preceded perhaps by dilatation of the vessel, owing to loss of its external support.

3. **The general effects** of the formation of an acute abscess of sufficient severity are **fever,** sometimes amounting to a **rigor,** and **leucocytosis.** A **rigor** consists of a definite series of phenomena, due to stimulation of the thermogenic centres by an accumulation of toxin in the blood. It is ushered in by a feeling of intense cold and discomfort; the features are pinched, and the teeth chatter. The skin, however, feels dry and hot, and the temperature of the body rapidly rises. After this stage has lasted a variable period, from ten minutes to half an hour, the patient gradually begins to feel warmer; the face becomes flushed; the temperature ceases to rise, and perspiration commences. Finally, there is a rapid fall of temperature accompanied by profuse sweating, which probably assists in the elimination of the toxin, but leaves the patient more or less exhausted.

Pus and its Constituents.—Pus is a thick, creamy fluid, having a specific gravity of about 1030, an alkaline reaction, and containing 85 to 90 per cent. of water. If allowed to settle, it separates into two layers, an upper or fluid part, the liquor puris, which is usually somewhat opalescent, and a deposit of a greyish- to slightly greenish-yellow colour, which is usually more bulky than the fluid portion. The liquor puris is derived from the plasma and consists of dilute albuminous fluid very similar to serum, and may sometimes undergo spontaneous coagulation after its removal from the body.

The deposit consists in the main of polymorph leucocytes, most of

which, as has been already pointed out, are dead and degenerated, whilst a few may still be living and capable of spontaneous movement. In addition, there are nuclei and other fragments of cells from the tissues, shreds of fibrous tissue, granular débris, and bacteria. Red blood-corpuscles are often present.

Muco-pus is a discharge from an inflamed mucous membrane; it is sticky or glairy from the presence of mucus. **Sero-pus** is thin and more liquid from an admixture with serum. **Blue** or **bluish-green** pus owes its colour to the presence of Bacillus pyocyaneus (*Pseudomonas pyocyanea*) (p. 45).

Occasionally an abscess contains not only pus, but also **gas.** This may be due to the existence of direct communication with a hollow viscus, *e.g.* the stomach or intestine, and hence is found in some cases of subphrenic abscess. In some of the many types of abscess associated with the appendix or other parts of the intestine, gas, when present, though it may be due to the activity of some member of the *Bac. coli* group, is probably most frequently produced by Bacillus welchii or Bacillus aërogenes encapsulatus (*Clostridium welchii*). In the limbs gas is also usually the result of infection with gas-producing anaërobic organisms, *e.g. Bac. welchii*, or bacillus of malignant œdema (*Cl. welchii* or *Clostridium œdematis maligni*). Occasionally gas develops in an abscess which is localized and has no connection with the bowel, the infection being probably of pyæmic origin. In gas-gangrene cases (see p. 113), *Cl. welchii* attacks and spreads in muscle especially, probably on account of the carbohydrate content of this tissue forming a suitable medium for its growth.

Treatment of Acute Abscess.—When an inflamed area is threatening to suppurate, the formation of pus can sometimes be **prevented** by elevation and rest of the part, together with the application of evaporating lotions and the administration of a dose of stock staphylococcal or mixed staphylococcal and streptococcal vaccine. Bier's treatment by induced hyperæmia may also be useful. In the case of an incipient boil, the inflamed area may be strapped firmly with elastoplast.

If, as already noted, the pus is not too abundant, it may occasionally be **absorbed** after its formation, more particularly when situated in a cavity of highly absorbing powers, such as the interior chamber of the eye (hypopyon) or the peritoneal cavity.

As a rule, however, one relieves pain and encourages suppuration by applying fomentations (medicated when necessary with opium or belladonna) or poultices to the part, and then, as soon as such suppuration has occurred, an incision is made to **evacuate** the abscess cavity. The opening must be large enough to prevent reaccumulation: it should be placed at a spot suitable for drainage, but as far as possible from sources of secondary contamination, and in such a direction that movements of the part do not close it. Where the opening is not dependent, it may be desirable to make a counter-opening by pushing the finger or an instrument through the abscess wall amongst the tissues, making it protrude beneath the skin at some dependent position, and cutting down upon it in this direction.

In dealing with deep abscesses in dangerous regions, Hilton's method may be advantageously employed. This consists in dividing merely the skin and superficial structures and then thrusting a pair of sinus or dressing forceps into the abscess cavity. On separating the blades forcibly a sufficient opening is made to insert a finger, or a drainage-tube. Rigid aseptic precautions must be taken in opening abscesses, for, although bacteria are present, it is essential that no fresh organisms be admitted, thereby giving rise to a mixed infection, the presence of which is most unfavourable to rapid repair. When an abscess is evacuated, it is always advisable to have the pus bacteriologically examined, and an emulsion of the causal organisms reserved for the preparation of an autogenous vaccine, which will thus be available, if necessary, for the further treatment of the case, and for the prevention of possible recurrences.

Any sloughs present should be removed, and when the abscess has burrowed, or if the cavity is large, it should be gently explored, but adhesions or bands crossing it should not be indiscriminately broken down, as they may contain blood-vessels, and care must be taken not to damage the limiting pyogenic membrane. All that is subsequently needed is to arrange for drainage, as by inserting a rubber drainage-tube or a slip of rubber or protective, and to prevent a mixed infection by a carefully applied antiseptic or aseptic dressing, or by packing the cavity with gauze soaked in an iodoform emulsion (10 per cent.). There is often a considerable loss of blood during the first twenty-four hours from the capillaries in the abscess wall owing to the sudden relief of tension; but this usually ceases of itself, or yields to moderate pressure. When once the abscess has been evacuated and drainage provided, if external contamination (mixed infection) has been avoided, the suppurative process should rapidly subside, the discharge becoming serous, and the wound closing and healing, and this in spite of the fact that bacteria are for a while present; they are evidently unable to develop or do harm as the result of a local immunity. An abscess cavity which has contained foul or stinking pus usually heals fairly rapidly if aseptic conditions are maintained, *e.g.* if no communication with the bowel exists, the discharge becoming free from smell in a few days. Infection with *Pseudomonas pyocyanea* is best treated by the application of eusol (5 per cent.) fomentations changed every four hours; they should be thick and of sufficient size. Deep wounds or sinuses should be irrigated with hot eusol.

The persistent discharge of pus from an abscess which has been opened usually points to inadequate drainage, due either to too small an opening or to one badly situated; to the retention of dead tissue, *e.g.* a sequestrum, or of foreign material, *e.g.* a piece of rubber tubing. In other cases the supervention of a mixed infection or the presence of a tuberculous or syphilitic lesion may be causing the discharge to continue, and occasionally it will happen that the patient's recuperative powers are not equal to dealing with the infection even after good and sufficient drainage. The cause must be ascertained and remedied, and attention must be given at the same time to improving the general

condition of the individual. In other cases undue pressure should not be maintained on acutely inflamed tissues by tight packs, drains, bandages, etc., as sloughing is very likely to ensue.

II. Chronic Abscess of Pyogenic Origin.

A chronic abscess may be defined as a collection of pus which forms slowly and without the signs of active inflammation, so that it is sometimes termed a 'cold abscess.' Although the majority are tuberculous in origin, a few are non-tuberculous and due to the liquefaction of other granulomatous masses, to an infection with pyogenic bacteria of low vitality, or to chronic pyæmia. The clinical phenomena are alike in the two types, and will be dealt with later (Chapter VI.), but there is one important distinction between them, in that the lining membrane of the pyogenic variety is merely granulation tissue more or less active, whilst in the tuberculous form it contains living tubercle bacilli. Hence, whilst a simple incision under aseptic precautions may be all that is required in the former, the latter also needs treatment directed against its tuberculous nature.

Sinus and Fistula.—When an abscess, acute or chronic, has been opened, and does not heal completely, either a sinus or a fistula may persist. A **Sinus** is a narrow track lined with granulations; penetrating into the tissues, open at one end and closed at the other; the discharge may be purulent or merely serous. A **Fistula** is an abnormal communication, congenital or acquired, between two cavities, or between a cavity and an external surface. When such conditions result from the non-closure of an abscess of pyogenic origin, the walls consist of an external fibro-cicatricial layer, and an inner lining of granulation tissue. Should the abscess have been of tuberculous origin, the lining membrane will also contain tubercles.

It is often a matter of difficulty to secure the healing of a sinus or fistula, and the following are the main causes of their non-closure: (1) The presence of some irritant persisting in the depths of the wound, such as a piece of clothing, the catgut ligature, silk thread or silver wire used in an operation, or diseased tissues, such as a fragment of dead or carious bone or, in the case of the jaws, a septic fragment of broken tooth: (2) the irritation of discharges, such as urine, fæces, or fœtid pus, finding an exit through the abnormal opening: (3) insufficient drainage of a deep cavity, so that there is always a certain amount of tension in the wound: (4) want of rest to the part, due either to voluntary movements, as in the limbs, or to involuntary muscular action in the immediate neighbourhood, as in fistula-in-ano: (5) tuberculous infection of the wall or closed end of the sinus, or an analogous actinomycotic or some similar infection: (6) the growth of epithelium along the walls of the sinus or round the margin of the fistula: (7) the presence around the sinus of dense sclerosed fibrous tissue which prevents contraction, or (8) of tumour-tissue, either previously present or supervening: or (9) constitutional debility.

The orifice of a sinus often looks depressed from the amount of infiltration around, but when the surrounding tissues are healthy,

puckering in of the orifice is a good sign. In cases where foreign bodies are lodged within, or where diseased bone exists, it is usually surrounded by prominent fungating granulations.

Treatment.—The removal of the cause should be the first aim in dealing with a discharging sinus or fistula. Foreign bodies or dead bone (if loose) must be removed, and diseased bones or tissue suitably treated. Efficient drainage is provided by dilating or incising the passage, or by providing a counter-opening in a dependent position. The granulation lining may need to be scraped away, and the raw surface disinfected by liquefied carbolic acid or sulphate of zinc solution (40 grains to 1 ounce). The cavity may be packed with gauze soaked in a hypertonic solution, such as glycerin and iodoform emulsion or 5 per cent. saline solution. Zinc ionization, diathermy, or the ultra-violet ray are sometimes useful. Rest to the part is provided by bandaging or by a suitable splint. Occasionally it is possible to excise the lesion completely and close the wound.

Should a fistula have become lined with epithelium, the edges will require paring, and some form of plastic operation must be undertaken to close the opening.

In addition, sinuses often react well to vaccine treatment, and this is especially the case with those left after empyema, when one or more injections of moderate doses of the causal organism will sometimes prove efficacious. Tuberculous sinuses, such as may be left after suppuration of lymph-nodes in the neck, etc., are occasionally curable by the use of tuberculin. Attention should in all cases be given to the general health.

Results of Long-continued Suppuration.—In certain cases, even though an abscess is treated antiseptically, and the formation of pus has ceased, the wound may not heal for months, but the discharge is merely serous, and, unless other organs and tissues are involved (a tuberculous fistula-in-ano, for example, may be secondary to tuberculous disease of the lung, intestine or both, from the swallowing of infected sputum), no constitutional results may be manifested. The temperature remains normal and the general health unimpaired, if no other disease is present. Should a tuberculous abscess become infected with pyogenic organisms, or a mixed infection occur in a pyococcal abscess, the discharge of pus continues or reappears, and fever to a varying degree develops. When an extensive or deep abscess is thus involved, the discharge may become profuse, high fever may supervene, grave visceral changes may follow, and the patient may lose his life through toxæmia and exhaustion. Long-continued suppuration is always an evidence of persistent infection, and amongst the conditions which arise therefrom may be mentioned hectic fever and amyloid disease of the viscera.

Hectic Fever may be defined as a chronic toxæmia due to the continued absorption of small doses of toxins, and is found in any condition of chronic infection, *e.g.* after acute, or in chronic suppurative affections of bones or joints, in tuberculous disease of the lungs where secondary mixed infection has occurred, and in chronic syphilitic or cancerous ulceration. It is characterized by a diurnal elevation

of temperature during the afternoon or evening, when the face becomes flushed (hectic flush of the cheeks), the eyes are bright and sparkling, the pupils dilated, and the patient feels better and stronger. The pulse, however, is small, compressible, and ten or twenty beats quicker than it should be. This condition continues till late in the night, by which time the temperature may have risen four or five degrees. In the early morning it falls as rapidly as it had formerly risen, and usually drops to normal, or even below it, and this is accompanied by profuse perspiration, which leaves the patient in a much exhausted condition. Day by day this continues, the fever and sweating together causing rapid and marked emaciation.

Amyloid, Waxy, Albuminoid, or Lardaceous Disease of various organs is a condition due to the deleterious effects of toxic compounds circulating in the blood,* whereby the delicate connective tissue of the walls of the arterioles, and subsequently the perithelial coats of the capillaries and the connective tissue of the walls of the veins, as well as, later, of the larger arterioles and small arteries, are converted into or infiltrated with a wax-like substance, from which lardacein, an extremely insoluble protein body, may be obtained. It may also come to involve the connective-tissue framework, basement membranes, etc., but never the cytoplasm of the special cells, of certain viscera. As this material is in no way akin to starch the name ' amyloid ' is a misnomer, but remains in common use. It occurs as a wax-like homogeneous material, becoming a dark mahogany brown on the application of tincture of iodine, and an inky blue when sulphuric acid is subsequently added. With methyl-violet the amyloid substance is coloured ruby-red, whilst normal tissues are stained blue. The organs mainly affected are the kidneys, spleen, liver, and villi of the intestines. The **liver** usually becomes uniformly enlarged to a considerable degree, often reaching from the fifth rib to the umbilicus or lower; it is firm in consistency, like indiarubber, and waxy-looking on section. The arterioles of the portal tracts and the capillaries in the intermediate zone of the lobules are those first affected. The secreting cells of the liver, kidneys, etc., may undergo compression atrophy and other secondary degenerative changes, but, as just noted, are not themselves invaded. The glycogenic and bile-producing functions are interfered with, so that the digestive processes, and especially the power of absorbing fats, are impeded, although the appetite may remain good. The **kidneys** become similarly enlarged, the change usually commencing in the arterioles leading to the glomeruli, but the intertubular capillaries and the basement membranes of the tubules are also early affected. In this stage the urine is very abundant (from the increased filtration through the degenerated vessel walls), pale, limpid, and containing a few hyaline† casts and fatty cells; later on, when secondary degenerative fatty and catarrhal changes have attacked the tubules, there is less urine, with a higher specific gravity, and a considerable amount of albumen. The **spleen** increases in

* Amyloid disease may also be due to syphilitic infection, and it occasionally occurs as a complication or sequel of repeated attacks of acute rheumatism.

† These are *never* ' waxy ' in the true technical meaning of the word.

size, but not always to so great an extent as the other viscera, the Malpighian bodies being the chief seat of the change. The capillaries in the **villi of the intestines** become lardaceous, and allow of an increased transudation of the fluid parts of the blood, resulting in diarrhœa, which may also be in large part due to the secondary catarrhal inflammation of the mucous epithelium which usually supervenes. The absorption of nutriment is thereby much lessened, and thus both by increased excretion and diminished absorption of food the strength of the patient is steadily undermined. It is most frequently seen in connection with long-continued suppuration in bone, but also occurs with phthisis and syphilis, especially when non-specific infection has been superadded.

In cases of chronic suppuration, amyloid degeneration in the viscera, far from being a contra-indication to operation, is rather to be considered as a sign that radical treatment is urgently necessary, unless the general condition of the patient absolutely forbids it. If by an operation, *e.g.* excision or amputation, the local disease can be eradicated, the amyloid change in the viscera, if still only in its earliest stage, may gradually disappear. At the same time it must not be forgotten that the kidneys are likely to have been seriously damaged, and that antiseptics, such as carbolic acid, which are absorbed into the blood and eliminated in the urine, may light up an acute nephritis, possibly with fatal results.

III. Focal Sepsis.

Much attention has been given of recent years to the widespread influence in the body of the absorption of organisms and their toxins from foci of **persistent bacterial infection,** whether suppurative or not. Various forms of disease have been traced to this cause, and it is interesting to note that many of the organisms concerned are normal inhabitants of the mouth or intestine, and lead to trouble only when absorbed into the tissues. The **resistance** of different patients varies, and may be seriously diminished by the long-continued action of the organisms upon the blood and blood-forming tissues. Such chronic infections with streptococci, even when comparatively mild, not infrequently give rise to a leucopenia, combined with a varying degree of secondary anæmia.

Such primary areas of **focal sepsis** may be found in various regions, but amongst the more important of these local lesions may be mentioned: (1) **Dental sepsis,** due either to apical infection with associated bone lesions, or to **chronic gingivitis** or **pyorrhœa,** either superficial or deep. The most important organisms present in these cases are streptococci of the non-hæmolytic types (see p. 43). For the diagnosis of dental infections, and for the detection of buried septic roots, and unerupted teeth which may have become infected, a complete X-ray examination of the teeth and jaws is essential; and in this connection it should be observed that not merely the grosser changes produced by an apical abscess should be looked for as evidence of infection, but also such less marked changes as thickening, beading, or calcifica-

tion of the periodontal membrane, increased translucency of the fangs, especially their apices, the presence of pulp-stones, etc., such changes being never exaggerated, but rather minimized, in radiograms, as is proved by subsequent bacteriological investigation of such teeth. When it is found necessary to remove several infected teeth, it may be wise to extract one tooth at a time, or only a few teeth, and not too large a number simultaneously. (2) **Naso-pharyngeal sepsis,** generally associated with **chronic nasal sinus** trouble, is usually streptococcal, sometimes pneumococcal in origin, or may be due to a mixed infection. (3) **Chronic tonsillitis** is often characterized by the presence of plugs of infective material buried deeply in the crypts and often encapsulated, although the tonsil itself may not necessarily be greatly enlarged, and may even be atrophied and sclerosed. (4) Various **intestinal** lesions, such as chronic appendicitis, colitis, cholecystitis, etc., may lead to the absorption of micro-organisms and their products; and such are often themselves secondary to dental, naso-pharyngeal or other lesions, but may persist when these have been removed or cured. (5) Chronic streptococcal lesions of the **urinary** and **genital tracts** in both sexes may produce similar results, for example in the cervix or Fallopian tubes in the female, or in the prostate or seminal vesicles in the male. It may also be noted that streptococci in very small numbers may from time to time find their way into the circulation from such areas of focal sepsis, and be excreted from the blood by the kidneys, and thus be found in the urine if catheter specimens are taken with extreme care, and a sufficient amount of centrifugalized deposit is inoculated into suitable media. In rheumatic cases this is most likely to be successful during an attack or exacerbation of the symptoms, as such streptococci may appear only intermittently in the urine. An autogenous vaccine prepared from them is often of great value in treatment.

Results of Focal Sepsis.—Only a few results of the absorption of bacteria and their toxins from areas of focal infection can be mentioned here. (1) The direct passage of bacteria from the mouth or naso-pharynx is likely to have an injurious effect upon the mucous membrane of the stomach or intestinal tract, and thus chronic gastritis, gastric or duodenal ulcers, appendicitis, or colitis are liable to follow, as also the extension of such infection along the biliary or pancreatic ducts, thus bringing about disease of the liver or pancreas, and perhaps leading to the production of gall-stones or of diabetes. In this connection it is important to emphasize the necessity for careful treatment of teeth and disinfection of the oral cavity before all operations on the mouth, such as excision of the tongue or tonsils, and also prior to gastro-enterostomy.

(2) The air-passages similarly may be infected by direct extension from oral sepsis; tracheitis with an abundant muco-purulent expectoration is often due to this cause, as is also aspiration pneumonia after an anæsthetic.

(3) The effect upon the blood of chronic absorption of bacteria and their toxins is to produce a secondary anæmia, mild or severe in type. Chronic infection, *e.g.* of the sockets of devitalized or 'dead' teeth,

with non-hæmolytic streptococci (*Str. salivarius, Str. mitis, Str. fæcalis*, etc.), which is so frequently associated with secondary 'rheumatic' and 'rheumatoid' manifestations, usually produces a varying degree of anæmia, especially a hæmoglobinæmia, accompanied by leucopenia. Infection with hæmolytic streptococci, *e.g. Str. pyogenes*, may also lead to a pronounced secondary anæmia, and leucocytosis may be present, though in bad cases a leucopenia affecting especially the polymorphs may supervene later.

(4) As regards the body generally, there are few organs which cannot be markedly affected, and the possibility of absorption of toxic material from some hidden or obvious source or sources—for these are often multiple—should always be considered. In particular, one would draw attention to the grave influence of such infections in the development of all the so-called rheumatic lesions, including synovitis, arthritis of many types, fibrositis, neuritis, perineuritis, endocarditis, etc. The development of chronic osteo-arthropathy has long been recognized as dependent on toxic absorption, and modern ideas as to the origin and treatment of many chronic lesions of bones, joints, fasciæ, ligaments, and of the eye, etc., are an extension of the same principle.

For treatment of the various lesions, see under special headings.

IV. Cellulitis.

Cellulitis is a disease characterized by the existence of a spreading inflammation of the subcutaneous or cellular tissues, due to the activity of, especially, pyogenic organisms, and going on perhaps to suppuration, sloughing, or even to extensive gangrene.

Causation.—The one essential is the infection of the cellular tissues with organisms. These may have gained entrance through a wound or abrasion, or by spread from some already infected focus. Deep infected wounds which are not properly drained are amongst the most favourable for the development of this condition, especially if the general health of the individual is bad, if he is suffering from albuminuria or diabetes, or if his surroundings are of an insanitary nature. Where much loose cellular tissue is present, inflammatory phenomena may readily supervene, from the absorption of bacteria from neighbouring contaminated structures, *e.g.* pelvic cellulitis arising from an infected uterus, or cellulitis of the neck from an ulcerated throat.

Bacteriology.—The *Streptococcus pyogenes* is the organism most frequently found in cases of cellulitis, particularly when there is much tendency to spread. In some of the more localized forms the *Staphylococcus pyogenes* is present.

Clinical History.—The symptoms necessarily differ according to the site of inoculation and the virulence of the organisms, and hence anything from a localized suppuration to the most acute form of spreading gangrene may result. In a case of moderate severity, due, say, to a prick or abrasion which has become infected, there is often a period of quiescence for a day or two, and the site of inoculation shows but slight signs of inflammation, beyond being a little tender.

The patient at first may feel only slightly unwell, but the symptoms, both general and local, tend to become progressively more marked. Fever is almost always present to a greater or less degree, and in the more severe types one or more rigors occur, or the temperature may be subnormal, owing to the intensity of the toxæmia. The affected part becomes hot, tender, and swollen; if superficial, it looks red and angry, and feels brawny. In some cases local hæmorrhages or petechial spots are found in addition to the other inflammatory phenomena. The course of the case depends to a very large extent upon the treatment adopted; if freely incised, the process may become limited, and even although suppuration and sloughing occur, repair may be readily effected. If, however, the infecting organism is very active, or the patient's power of resistance low, or if the inflamed area is left to itself or merely poulticed, the process may spread rapidly, and extensive destruction follow. Intense pain and sleeplessness, accompanied perhaps by delirium, form the most prominent symptoms, and these, together with the toxic fever, rapidly exhaust the patient's strength. Though often of slow development, definite and localized suppuration may at length occur, or the swelling may remain hard and brawny for some time in such a region as the neck, with no evidence of softening, so that it may be difficult to determine whether actual localized abscess formation has supervened or not. The infiltrated cellular tissues are likely to slough, and in a limb extensive subcutaneous necrosis may occur, although the skin gives way only in places; hence it is often possible to pass a probe between the skin and the deep fascia over a considerable area. Sometimes the chief focus of inflammation may be found at a distance from the original site of inoculation, whilst the intervening portion is but little affected, or shows the characteristic features of acute lymphangitis. This is due to the organisms being transmitted along the lymphatics, and then arrested at some point further along their course. Occasionally the infection spreads along the deeper areolar planes, or even along muscle substance, which may be infiltrated with pus or may actually slough. In all these more severe forms the patient runs a considerable risk of developing general septicæmia or pyæmia.

Treatment.—Careful attention to the principles of antiseptic and aseptic surgery can prevent the occurrence of cellulitis to a very large extent in casualty and operative work. Any wound, whether deep or merely superficial, must, after the immediate application of tincture of iodine or other suitable antiseptic, be protected from further infection. Should inflammatory phenomena occur, the application of warmth and moisture in the form of mildly antiseptic fomentations or poultices may be sufficient, whilst attention should be given to free action of the kidneys and bowels and to the general health. If, however, a spreading cellulitis supervenes and suppuration is threatening, free incisions, *e.g.* in the long axis of a limb, should be made into the brawny tissues, so as to give exit to the serous and irritating discharges, but the deep fascia must if possible be avoided, and should not be incised unless the infection has already spread to the cellular tissue beneath it. The wounds thus made are lightly packed with gauze

soaked in a hypertonic solution (*e.g.* 5 per cent.
cent. glycerine and iodoform emulsion), over wh
are applied. The object of this is to drain the
capillary action, and hence an effective juncti
between the gauze drain and the surrounding dr
to incorporate a piece of sterilized gutta-perch
in the outer folds of the dressing, so as to ke
encourage a free discharge. Packing with g
is also useful, or the Carrel-Dakin method of
sometimes be employed with advantage. Ext
requires further incisions.

After the bleeding caused by the incisions h
part should if possible be immersed several time
for not more than two hours at a time, so as t
render them innocuous. Sterilized normal salt
ture of 105° to 110° F. may be used, or weak
eusol, but *antiseptics are of comparatively littl*
disease when once started; the surgeon has to
of tension, the removal of toxic discharges, an
of the tissues. At the same time the utmost
prevent any fresh or mixed infection, and imn
should be insisted upon whenever possible.

The **general** treatment is that indicated f
including the use of antistreptococcal serum
transfusion. The administration, preferably
route, of collosol manganese is often useful. P
ing food, with suitable vitamin content, is a
drugs as are required to procure sleep and se
the bowels, skin, and kidneys.

Special Varieties of Celluli

Cellulitis of the Axilla may be due to a local
say, during the removal of the axillary hair;
follows an infected wound of the hand, such
or post-mortems, and hence is not uncommon i
students or nurses. It may also be caused
axillary lymphadenitis. The tissues of the ar
brawny, the pain is severe, especially on mov
and the disease is liable to spread towards t
between the pectoral muscles; it may also tra
sloughing of the capsule, invade the shoulder-
to an acute arthritis.

Treatment.—Early and extensive incisions a

layer of loose areolar tissue; it may, however, follow a simple laceration of the scalp and remain superficial. In the latter case the scalp becomes red, œdematous, and tender, but the inflammation remains more or less localized; in the former, pus forms beneath the aponeurosis, and extends to its limits of attachment, so that abscesses are likely to point in the forehead just above the eyebrows, over the zygoma, or along the superior curved line of the occipital bone. The whole scalp may become separated from the bone, and the patient runs a risk of necrosis of the cranial bones and of intracranial complications. The scalp itself, however, rarely sloughs owing to its abundant vascular supply.

Treatment.—This consists in making early and free incisions parallel to the lines of the vessels.

Cellulitis of the Orbit is not an uncommon sequel of penetrating wounds in this region, owing to the difficulty of disinfecting and draining them. It may also be secondary to suppuration in the cranial venous sinuses. The orbital tissues become infiltrated and swollen, the eyelids œdematous, and the eyeball pushed forwards (proptosis). The inflammation may spread directly to the meninges, or through the veins to the cavernous sinus. Necrosis of the orbital walls may also occur, whilst the eye itself may suffer, either from an infective panophthalmitis due to lymphatic infection, or from optic neuritis secondary to retro-ocular inflammation and pressure, or, at a later period, from optic-nerve atrophy secondary to cicatricial contraction around the nerve. If the cellular tissue of the orbit sloughs, the subsequent movements of the eyeball may be much hampered, or indeed lost, whilst the lids may be drawn back to such an extent as to prevent their complete closure.

Treatment.—No penetrating wound of the orbit ought to be closed if there is any question of its infection; indeed, it is often wise to increase its size slightly, so as to enable the deeper parts to be cleansed and drained. If cellulitis follows, the original wound must be opened up, and possibly fresh incisions made either through the lids or through the fornix conjunctivæ. Fomentations are then applied. If panophthalmitis supervenes, the eyeball must be incised crucially; this is a safer proceeding than enucleation, which is more liable to be followed by meningitis.

Cellulitis of the Neck is usually secondary to lesions of the mouth or throat, and may, for example, be associated with follicular tonsillitis, diphtheria, or scarlet fever, the process probably starting in a deep lymph-node; it occasionally follows operations on the neck, or may be due to suppuration in the mastoid cells. If the infection is beneath the deep cervical fascia, the affected side of the neck becomes swollen, red, and brawny; severe pain of a deep tensive character is experienced, and this is increased by movements of the head or jaw. The swelling is often peculiarly hard and resistant, and, although œdema may be present, it may be several days before the surgeon can detect any focus of softening suggestive of suppuration. During this period the constitutional symptoms are severe; fever may be high, and the pain and consequent sleeplessness may exhaust the

patient, whilst the difficulty of swallowing hinders nutrition. Dangerous symptoms arise from pressure on important vessels and nerves, from extension of the inflammation to the mediastinum or to the glottis, causing œdema and consequent dyspnœa, or from the supervention of pyæmia owing to venous thrombosis. The process usually ends in sloughing of the cellular tissue and suppuration, the pus burrowing widely if a free exit by incisions through the deep fascia is not provided.

Treatment.—The causal lesion in the throat must be attended to, any operation wound freely opened up and drained, and the general condition improved by the administration of nourishing fluid food, stimulants, and quinine. Antistreptococcal serum may also be injected, but sometimes antidiphtheritic serum has been found equally useful; immuno-transfusion may also help. Locally, fomentations are applied at first; but on the onset of suppuration, or before, if the pressure symptoms are severe, or if the affection is obviously extending, free incisions must be made along lines of safety through the deep fascia, so as to relieve tension and give exit to discharges. It must be remembered that the tissues are matted together in such a way as to render their recognition difficult; and inasmuch as the pus often lies deeply, the greatest caution has to be taken to avoid injury of important structures.

Special interest has been directed to a form of this affection which occurs in the submaxillary region, and is known as **Ludwig's angina.** It is usually secondary to some focus in the mouth, or may occasionally result from the extension of inflammation through the capsule of lymph-nodes, or it may originate in disease of the middle ear, the infection spreading down along the posterior belly of the digastric. The swelling in these cases extends forwards beneath the chin, and may involve the floor of the mouth and base of the tongue, pushing that organ forwards, and even making it protrude from the mouth. Œdema of the glottis may supervene, or a sublingual abscess form. Treatment is similar to that indicated above, and one or more incisions may be required. Œdema of the glottis will probably require tracheotomy.

Pelvic Cellulitis is an infective inflammation of the loose cellular tissue which ensheathes the pelvic viscera. It may result from any penetrating wound, accidental or operative, which encroaches on this region, *e.g.* extraperitoneal rupture or perforation of the bladder, suprapubic or lateral lithotomy, injudicious catheterization, curetting the uterus, and it is a common sequel of unskilled attempts to induce abortion. It may also be due to the spread of bacteria from any of the pelvic viscera, *e.g.* the bladder, prostate, rectum, uterus, or Fallopian tube. It is associated with all the local and general signs of deep inflammation, and often, indeed, with peritonitis, giving rise to a tense, firm, painful swelling, to be felt *per rectum* or *per vaginam*, and sometimes to an indurated mass of inflammatory effusion, dull on percussion, above the pubic arch. Abscesses may form, bursting either externally above Poupart's ligament or into some of the viscera, or possibly in both directions, producing intractable forms of urinary

or fæcal fistulæ, whilst venous thrombosis and pyæmia from the breaking down and dissemination of the infected blood-clot are likely to develop.

Treatment.—The surgeon may be called in to such cases in the early pre-suppurative stage, when rest, limitation of diet, small doses of opium, and fomentations to the hypogastrium, with hot rectal or vaginal douches, should be adopted. At a later stage, when pus has formed and the abscesses need to be opened, an incision is generally made just above Poupart's ligament and close to the pubic spine; the abdominal muscles are divided to a sufficient extent to enable the surgeon to work downwards between the transversalis fascia and the peritoneum, which, in the female, must be pushed aside in order to reach the broad ligament, where pus is frequently found. As soon as the subperitoneal tissue is opened the knife should be discarded, and only blunt instruments or the fingers employed. The cavity of the abscess should be efficiently drained, and for this a counter-opening through the vagina may be required.

Intestinal obstruction from the contraction of cicatrices may develop as a remote sequel of such cellulitis, and hydronephrosis may arise in the same way from pressure on the ureter.

V. Wound Infection.

When a wound, whether accidental or operative, has become infected with micro-organisms, healthy repair is retarded or may even cease, and is replaced by an inflammatory process usually of a suppurative type. In accident cases, wound infection is often unavoidable, due to the dirty state of the skin or the nature of the accident; and, however thorough the subsequent disinfection, it may be impossible to render the parts sterile. Still more does this hold good in military surgery. In operative work wound infection in a previously non-septic case is usually due to some avoidable mistake or oversight, only occasionally to auto-infection. Ineffective sterilization of silk or catgut is perhaps the most frequent cause, since the introduction of rubber gloves has largely safeguarded the patient from infection from the hands of the surgeon and his assistants. Devitalization of the tissues as a result of rough handling or prolonged exposure and faulty hæmostasis are, however, important predisposing elements. The organisms present are exceedingly variable, as might be expected. In post-operative cases staphylococci are usually found, but the worst cases are generally due to streptococci or to a mixed infection. In casualty and still more in military work a mixed infection is generally present, often including anaërobes, as well as the above.

The **local** trouble may manifest itself merely as an acute or subacute suppurative process within the wound, or as an active cellulitis spreading into the adjacent tissues.

In post-operative cases it may commence deeply around a buried stitch, or more superficially. In the latter case the lips of the wound look red and puffy, the tissues often swell up between the stitches, which look as if they had become too tight, and on introducing a

probe pus may escape; the patient complains of pain, usually of a throbbing nature, and there is some rise of temperature and in bad cases even a rigor. In the milder forms, the changes are limited to the immediate neighbourhood of the wound; but, if neglected, or in an unhealthy subject, or if due to virulent organisms, the phenomena of an acute cellulitis may supervene.

When the process starts in the deeper parts of the wound, nothing may be obvious for a few days, except perhaps some fulness and tenderness on pressure, together with some slight rise of temperature. Sooner or later an abscess develops and may come to the surface, in which case a sinus is likely to be left until the offending material, *e.g.* a ligature or buried stitch, has been absorbed or removed. The same holds good as regards silver wire, screws, plates, etc., which, when implicated, must be removed before healing can take place.

Cases due to accident are often seriously complicated by the carrying in of infected material, such as portions of the patient's clothing, soil from the road, dirt or grease in machinery accidents, etc., and the bacteria derived therefrom, or from the patient's skin, find an abundance of suitable material for their development in the torn and damaged tissues. The results of such contamination necessarily vary with the depth to which the lesion has extended, and may consist of sloughing of and suppuration in and amongst the various structures affected. Pus tends to track and burrow along opened-up planes of tissue, and the swelling of the more superficial parts aggravates the condition by hindering mechanically the escape of exudate from the deeper parts.

The **General Phenomena** connected with wound infection vary chiefly with the nature and virulence of the infecting organisms, whether these produce active toxins, and whether or not the blood itself becomes invaded.

1. **Toxæmia.**—This results from the absorption of toxic material from some focus of infective inflammation of sufficient extent and virulence. A small collection of pus under pressure is capable of giving rise to marked toxic symptoms, whilst in spreading inflammations, such as erysipelas and other forms of cellulitis, the manifestations are often of a grave type. The same is true of infective inflammation of the peritoneal cavity, especially when the upper half is involved, since the communication with the lymphatics of the diaphragm is very free. Toxæmia is not infrequently associated with a true septicæmia, and clinically it may be almost impossible to distinguish between the two.

The **Symptoms** are fever (except in some of the gravest cases, when the temperature may be subnormal, although the pulse may still remain high), accompanying loss of appetite, a dry tongue, a quick pulse rapidly becoming weak, severe headache, and perhaps delirium. The patient is at first constipated, but vomiting and diarrhœa may ensue from gastro-intestinal irritation, followed, it may be, by exhaustion, collapse and death, the latter perhaps preceded by coma. Dyspnœa from pulmonary congestion and the action of the toxins upon the myocardium, and albuminuria, also occur. Effective treatment of the cause, as by opening an abscess or drainage, may lead to

a speedy disappearance of the symptoms, but in spreading inflammation the toxæmia may not subside for some time. Should an attack prove fatal, the post-mortem manifestations are practically identical with those of a septicæmia, but the blood is free from infective bacteria.

2. **Septicæmia.**—Should the organisms not only develop in the tissues, but also find their way into the blood, septicæmia results (p. 74), but the stage at which the latter supervenes is in individual cases not easily determined.

3. **Pyæmia.**—Bacteria may escape into the blood, not only as detached invaders, as in bacteræmia and septicæmia, but occasionally in septic emboli, giving rise to pyæmic abscesses (see p. 76), and these abscesses may thus be found in a patient who also shows obvious signs of acute toxæmia.

The Local Treatment of an Infected Wound necessarily varies with its situation, the length of time which has elapsed since the infection and with the conditions present.

In a Mild Post-operative Infection the relief of tension and the application of warmth and moisture to the part to encourage the local reparative activity of the tissues usually suffice. Stitches, both superficial and deep, must be immediately removed, and the wound widely opened up so as to give free exit to the discharge. Undue interference, as by scraping, squeezing, syringing, etc., is to be deprecated, as thereby the infection may be disseminated. It is futile to apply strong antiseptics, since the organisms have penetrated into the tissues and cannot be destroyed without also involving these structures; moreover, the phagocytic power of the leucocytes is thereby checked. Some of the more modern antiseptics, such as the hypochlorites or flavine, are less objectionable and may be useful on occasion; but it is possible that the benefits which follow their judicious employment are due to causes other than their antiseptic qualities.

Sloughs may be cut away, but generally are left to separate by natural processes, assisted perhaps by the use of hypertonic substances, such as gauze soaked in salt solution (5 per cent.), or glycerine and iodoform (10 per cent. emulsion). If there is a considerable cavity in the depth of the wound, it may be desirable to drain it by introducing a strip of sterilized rubber glove or a rubber drainage-tube. Otherwise the wound is lightly packed, and warm moist applications, *e.g.* boracic fomentations, are applied. In Ludwig's angina, the pathological process is mainly concentrated in the plane subjacent to the mylohyoid muscle, and the tension cannot be completely relieved without transverse section of the fibres of that muscle. The bowels must be freely opened, and attention paid to the general health of the patient. In a few days, when granulations have formed, the wound may be irrigated with normal salt solution or swabbed out with peroxide of hydrogen. Healing is finally brought about by granulation, but can sometimes be hastened by strapping the edges of the wound together, or by grafting.

If such a régime does not suffice to stop the process, the wound must be still further opened, and the spreading infection followed up—in fact, it is treated as a cellulitis. Sometimes great benefit is derived

from the use of a poultice made of linseed (flax-seed) meal and boiling boric acid lotion, placed between layers of cyanide gauze; this type of poultice is aseptic, and retains its heat better than a fomentation, whilst it is softer and adapts itself more readily to irregularities of surface. In other cases the Carrel-Dakin treatment (p. 69) may be instituted.

In a Gravely Infected Wound, the immediate treatment is governed entirely by the length of time which has elapsed since its infliction. *During the first eight to twelve hours bacteria do not penetrate deeply* into the tissues, and the limited number primarily admitted take some time to multiply. Hence within twelve to twenty-four hours of its infliction there is good hope of effecting complete sterilization of the wound by mechanical or chemical means.

Early Attempt to Sterilize a Wound.—The patient is anæsthetized and the clothing removed. Hæmostasis is effected, and the wound cavity temporarily packed with gauze soaked in some suitable antiseptic (*e.g.* iodine, carbolic lotion 1 in 20, Dakin's solution, a strong solution of brilliant green, or any other that the surgeon favours), and the surrounding skin shaved and cleansed. Tincture of iodine, either full strength or diluted half with 95 per cent. alcohol, is in very general use for the first antiseptic treatment of wounds. The excess is removed from the wound by pouring in alcohol. The skin is sterilized by washing with ether or benzine and painting with tincture of iodine, the iodine being removed with alcohol; or a mixture of picric acid, 5 per cent., dissolved in 95 per cent. alcohol may be used. In very dirty cases it may be desirable to begin with turpentine, and then to wash the skin with an ethereal solution of soap, finally employing either azochloramid or an alcoholic solution of biniodide of mercury, but other suitable solutions may be utilized. The wound itself is then uncovered and investigated.

The bruised and torn margins of the wound are excised, as also all dead and damaged deeper tissues. Muscle tissue is carefully examined, especially in street accidents or gunshot lesions, as gas gangrene may develop therein. The exposed fibres are cut away until tissue with a healthy vascular supply (as shown by its rapid reaction to gentle pinching with forceps) is reached. Where the tissues have been in contact with road dirt or soil, a prophylactic dose of anti-gas gangrene serum and also antitetanic serum (see pp. 115 and 127) should be administered as early as possible and repeated if necessary. Foreign bodies and dirt are removed, and the skin wound is, when necessary, enlarged along lines of safety in order to expose the deeper parts.

If the surgeon is satisfied with the appearance of the tissues thus laid bare, he may proceed to close the wound by **Primary Suture,** with or without the application of such diffusible antiseptics as ether or spirit (possibly in combination with biniodide of mercury, 1 in 500). Other surgeons prefer to protect the tissues by rubbing in B.I.P.P. (p. 70), after cleansing with alcohol. Closure is best effected by through-and-through silkworm-gut sutures; it may be advisable to make some provision for drainage.

If the surgeon is doubtful as to the condition of the wound, it is wise not to close it at once, but to pack the cavity with gauze soaked in flavine (1 in 1,000), or impregnated with B.I.P.P., or to treat it by the Carrel-Dakin method. If at the end of two or three days the

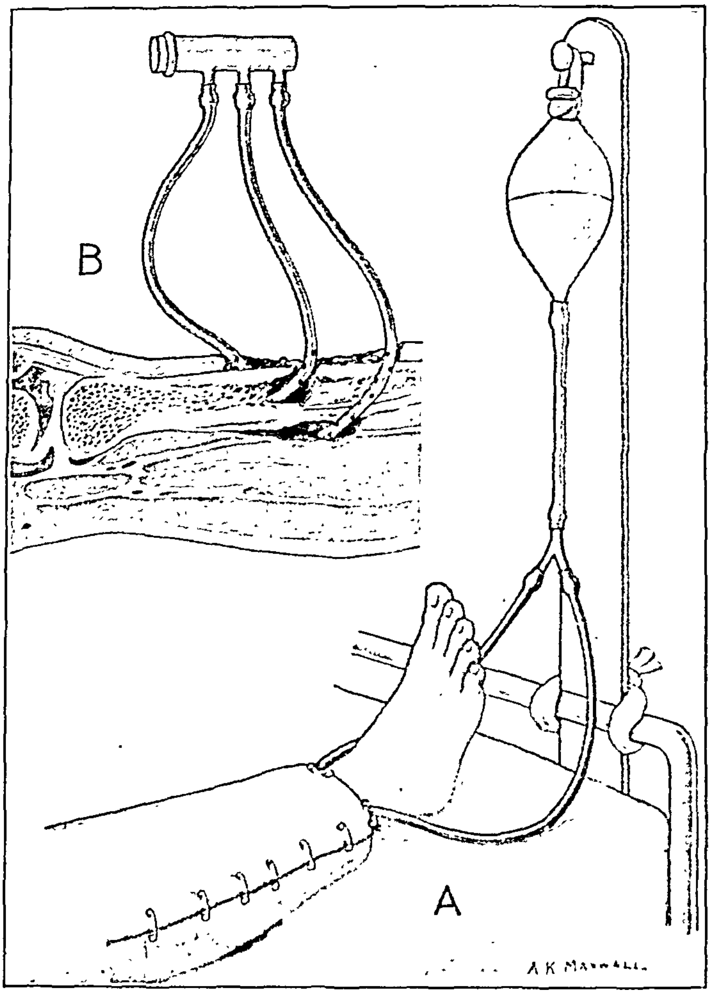


FIG. 21.—CARREL-DAKIN METHOD.

At A is seen the flask or other container suspended at the end of the bed, and from it descends a rubber tube commanded by a clip; it divides below into two branches which pass in beneath the external gauze and wool dressing to the wound.
At B the method of placing the tubes in an infective wound of the tibia.

wound is practically sterile, or the discharge therefrom contains only a few bacteria, **Delayed Primary Suture** may be undertaken. A bacteriological examination of the discharge is most important, particularly with a view to determining whether or not streptococci, especially if of hæmolytic type, are present, as, if this be so, it is useless and dangerous to attempt suture.

If at the end of two or three days the infective process is active and numerous bacteria are present, then treatment as for cellulitis by one or other of the methods indicated below must be carried out; and healing occurs by granulation, assisted perhaps by grafting or hastened by **Late Secondary Suture.**

The treatment of broken bones is not described here, but if present they must be dealt with in accordance with the plans outlined in Chapter XX.

The **Carrel-Dakin Treatment of Wounds** is dependent on the antiseptic properties of the hypochlorites, especially of Dakin's solution, which destroy bacteria, but do no serious damage to the phagocytic activity of the leucocytes or to the reparative power of the tissues. It is essential to open up and cleanse all the depths of an infected wound; dead and badly damaged tissues are removed, but it is not always necessary to provide dependent drainage, and indeed the wound which can be most readily treated by this method is one which can be kept full of the solution. Multiple rubber tubes with a calibre of 4 mm. and of suitable length to command all the depths of the wound, entering into all pockets, are introduced and kept in place by strips of gauze, soaked in Dakin's solution, placed amongst them and between them and the walls of the cavity. These tubes are closed at one end, but perforated for a variable distance by minute apertures (Fig. 21); in a large wound it is possible that six, eight, or even twelve such tubes may be required. Their free ends are gathered up by glass connections (single to four-fold) which link them by larger tubes to one or more reservoirs above the bed, from which a limited quantity of Dakin's solution is allowed to escape every two to four hours so as to irrigate the wound. If no reservoir is available, a syringeful of the antiseptic is squirted down the main tube; a clip is subsequently placed on this tube so as to prevent regurgitation, and thereby ensure the escape of the fluid through the tiny perforations into the depths of the wound. The tubes pass to the wound between layers of gauze soaked in the solution and through a sheet of sterilized non-absorbent wool in a gauze cover. The Dakin's solution is sometimes irritating to the skin, especially if free alkali is present, and to prevent this the parts around the wound should be protected by layers of gauze infiltrated with sterilized vaseline. The amount introduced need not be great, but provision has to be made to prevent the bedding from getting wet, as the solution has a damaging effect on bed-linen. When the healing is progressing satisfactorily, and secondary suture is not contemplated, a chloramine ointment is useful. It should consist of chloramine-T, 10 parts; stearate of soda, 86 parts; and water, 4 parts.

When properly carried out, this treatment is most valuable, but it requires very careful organization of technique and efficient assistance. The bacterial content of the discharge from the wound is tested from time to time, and, as the hypochlorite takes effect, the number of organisms gradually diminishes until in ten to fourteen days, perhaps, only one bacterium may be found in several microscopic fields of the smear. The wound is then regarded as clinically sterile, and secondary suture may be adopted. The absence of fever and toxæmia

is remarkable, the patient's sufferings are much reduced, the amount of reactionary injury to deeper tissues is minimized, and hence repair is more rapid and accompanied by less mutilating disabilities and disfigurements than under other circumstances. The opportunity of undertaking secondary operations on damaged nerves or bones at an early period is of great value.

Treatment with B.I.P.P. (Bismuth-Iodoform-Paraffin-Paste) is simple and valuable. It consists in opening up and cleansing the wound mechanically by excision of damaged tissues or friction with gauze swabs. Complete hæmostasis must be secured, and the wound is then swabbed out with alcohol. The surface is rubbed over with swabs, covered with an antiseptic paste consisting of bismuth subnitrate, 1 part; iodoform, 2 parts; and sufficient liquid paraffin to make the paste of the consistency of clotted cream. In preparing the paste, each element must be previously sterilized, the iodoform by washing with 1 in 20 carbolic lotion, the bismuth and paraffin by dry heat at a temperature of 120° C. for half an hour. The bismuth and iodoform are mixed in a sterile mortar, and the paraffin is slowly added and well stirred, so that no lumps or gritty masses occur. The B.I.P.P. should be gently but thoroughly applied to the surface of the wound, being carefully rubbed in with a sterilized swab, especially into the muscles, so that a thin film covers all the tissues; lumps of the paste must not be left in the depth of the wound, and no undue quantity must be employed for fear of toxic symptoms; a drachm is usually quite sufficient even for a large cavity. If the wound shows no tendency to ooze and its condition appears to be otherwise favourable, complete suture without drainage may be adopted. In less favourable conditions the wound is left open and packed with sterile gauze; unless any special cause for re-dressing supervenes, the wound is left for five or six days; on removing the gauze the wound looks very dirty, being covered with a mixture of pus and paste, but on washing this away with sterile salt solution the surface should now appear healthy, and granulations be found beginning to form. A similar dressing is reapplied, and may often be left for another period of five or six days, when reparative activity should be fully established.

Secondary suture is often possible in these cases; the skin around is thoroughly cleansed, and the margins excised and undercut for a short way. The granulations are freely curetted; bleeding is stopped completely; the surface is swabbed out with ether or alcohol, and carefully 'bipped'; sutures are introduced, buried ones of catgut to close muscular gaps, and deep ones of silk or silkworm gut to command the main wound, whilst fine catgut stitches bring the margins of the skin into accurate coaptation.

Some surgeons, especially in the United States, consider it bad practice to close a wound suspected of being infected and to rely on some incorporated antiseptic such as B.I.P.P. to prevent infection. If there is the slightest doubt a drain is used, and efforts are directed toward the production of a lymphorrhœa from the wound by the use of hypertonic salt solution.

Toxic symptoms have occasionally occurred as the result of the employment of B.I.P.P., chiefly from bismuth poisoning. A blue discoloration of the gums occurs, which may also appear on the mucous membrane of the cheeks and tongue. Gastro-intestinal disturbances may also sometimes arise in the form of colic and diarrhœa, and a few fatal cases have occurred; ulceration and sloughing of the sigmoid have been found in some of these. Care must also be taken that the paraffin is pure; some cases of irritation around the margins of the wound have been traced to imperfectly refined paraffin.

Finally, it must be pointed out that the presence of this paste in the wound interferes with X-ray examinations, since bismuth casts a shadow, and that excess of the paste may lead to a persistent sinus or even to a secondary abscess which can heal only when such excess has been discharged.

The use of the aniline dye, **Flavine,** in a solution of 1 in 1,000, has been advocated by some who claim that its antiseptic powers are enhanced by the presence of blood-serum (which hinders the action of the hypochlorites), that it has no deleterious effect on phagocytosis or tissue activity, that it is a stable non-toxic compound, and that its effects in a septic wound are most marked when gauze soaked in a solution of the dye is kept in close and persistent contact with the tissues. Bacteria are said to be quickly destroyed and wound sterilization rapidly accomplished. Most observers, however, do not agree with these claims, but maintain that, whilst the exudation of pus is checked or aborted, the process of repair is also delayed and the growth of epithelium hindered, so that, at the end of a week, although there may be no pus in the wound, yet the surface looks much as it did at the start; after a time a yellowish film or pellicle forms in which the superficial layers of the exposed tissues are incorporated, and the wound takes on the appearance of a callous ulcer. If now the flavine is discontinued and other applications, such as normal salt solution or eusol, are substituted, the wound as a rule quickly assumes a healthy aspect.

Sir Almroth Wright's Physiological Method of Treating Wounds with a hypertonic or isotonic solution of sodium chloride was introduced during the Great War because of the difficulties encountered in applying the ordinary aseptic and antiseptic measures for dealing with wounds found sufficient in civilian work, the delay often experienced in bringing the wounded under treatment allowing extension of the infection.

The chief means of cure when such an infection has once developed reside: (1) In the lymph, which when fresh has decided antibacterial properties and also considerable anti-tryptic power; this latter increases rapidly in an infected person, but is lost if the lymph becomes 'stale': (2) in the leucocytes with their phagocytic powers, bringing to an end bacterial activity, and thereby encouraging reparative changes (3) in the tissues, which, when once the bacteria are seriously weakened, assert their natural tendency to repair.

The agent recommended by Wright for counteracting the deleterious processes at work in the wound and for stimulating the reparative

activities is a solution of sodium chloride, either hypertonic or isotonic.* **Hypertonic salt solution** (5 or 10 per cent.) acts beneficially in several directions: (1) It encourages lymph drainage of the tissues, and thereby not only removes stale lymph and replaces it by fresh and active lymph, but also restores the vascular supply of the tissues by modifying the 'lymph-bound' condition of the parts. (2) It also limits leucocytic emigration and therefore reduces the amount of pus excreted. (3) It disintegrates any leucocytes with which it is brought in contact, and sets free a limited amount of trypsin in the wound which can act upon the sloughs and loosen them by erosive digestion; this power is held in check by the anti-tryptic influence of healthy lymph. From these facts it is obvious that hypertonic salt solution will be of most value in the treatment of the earlier stages of an infected wound. There comes a time when its beneficial influence is lost, and indeed it may be positively harmful, and then the surgeon may wisely employ the **isotonic** or **normal salt solution** (0·85 per cent.), which attracts leucocytes and favours phagocytosis.

The value of the application of hypertonic solutions to infected wounds cannot be denied, but it is not only sodium chloride solution which thus acts beneficially. Other agents, such as glycerine, as in the old-fashioned iodoform emulsion (10 per cent.), and perhaps Dakin's solution, act in this way. It must be admitted, however, that some surgeons attribute these benefits, not to the osmotic action, but to the continued moisture, which loosens any dried clot or lymph on the surface, and permits a more abundant flow of lymph from the tissues.

The method of application of hypertonic solutions varies widely with the character of the wounds. In accessible superficial lesions all that is needed is to apply to the surface moderately thick pads of sterilized lint or gauze soaked in the solution, and keep them covered with a layer of jaconet. This dressing is renewed frequently. In other cases where repeated changing of dressings may do harm, the lint or gauze is kept moist by allowing the solution to drop on to it from a suitable reservoir. In deep wounds the solution may be carried into the deeper part by tubes and allowed to escape from the wound on the Carrel system.

Wounds treated in this fashion rapidly take on a characteristic appearance. They become clean, of a pink colour, and are covered by a thin layer of granulation tissue from which little or no pus is

* The influence upon the tissues of various fluids brought into contact with them differs with their specific gravity and density, and may be illustrated by the effect on red blood-corpuscles of varying strengths of salt solution. An isotonic solution (0·85 per cent.) has no osmotic pressure on either side, and the red cells remain unharmed. A hypertonic solution (5 per cent.) exercises considerable osmotic pressure or attraction of fluid towards the solution itself, and fluid is withdrawn from the red cells, which become shrunken and crenated. A hypotonic solution, on the other hand, allows the cells to absorb fluid to such an extent that they swell up and burst, and thus the injurious influence of plain water on the tissues is in part explained. It is only necessary to irrigate the nasal fossæ firstly with normal salt solution, which is comforting, and then with plain warm water, to appreciate the irritating influence of the latter agent on the tissues.

discharged. The organisms, too, are greatly reduced in numbers. Such wounds heal slowly, if at all, unless the hypertonic is replaced by normal saline solution, and then the surface of the wound becomes greyish and discharges a considerable amount of pus, but granulation quickly occurs and healing goes on satisfactorily.

It must not be forgotten that Wright himself admits that dead spaces in the tissues, *i.e.* spaces in which pus can collect, must be effectively opened up and drained before any good can follow the use of hypertonic salt solution, and it is not improbable that much of the value of his method depends on suitable removal of dead tissues and effective mechanical drainage of the wound, and these have long been recognized as constituting essential elements in the treatment of infected wounds.

VI. Septicæmia.

Septicæmia is the condition of infection of the blood by bacteria and their proliferation therein. It differs from pyæmia in the absence of secondary abscesses (although, as explained later, it may be associated with it), and from toxæmia by the fact that the latter is due merely to the absorption into the blood of toxins generated in a diseased focus in which the bacteria themselves remain localized. In other cases, again, the process is rather that of an overflow phenomenon, in which the organisms gain access to the blood-stream from some septic focus, but do not proliferate in the blood itself—a condition to which the term **bacteræmia** is now applied. In both septicæmia and bacteræmia the organisms circulate in the blood, though in many cases, especially of bacteræmia, in but scanty numbers, and periods may occur in which no bacteria can be detected in the blood, so that too much weight should not be attached to a single negative bacteriological result, which has been obtained from the cultures of only a few c.c. of blood.

Bacteriology.—The commonest causal organisms are streptococci (p. 43), which are almost always present in puerperal septicæmia and in ulcerative endocarditis. Next in frequency is the *Streptococcus pneumoniæ* (or pneumococcus). Staphylococci are also fairly common organisms in this condition, and the prognosis may then be rather less grave.

Rarer causes are *Bac. coli* and allied organisms, Bacillus pyocyaneus (*pseudomonas pyocyanea*) and the gonococcus (*Neisseria gonorrhϾ*). It may also be noted that the specific organisms of certain of the acute infective fevers, *e.g.* typhoid and paratyphoid, may be found in the blood, especially in the earlier stage of these infections; whilst the septicæmic forms of anthrax and plague are conditions of the utmost gravity and often prove fatal.

Clinical History.—Septicæmia occurs most commonly from direct inoculation with virulent streptococci through small lesions, such as post-mortem wounds, or from scratches or punctures with infected pins or instruments; in rarer cases it follows operation wounds and severe lacerated injuries. It is the usual accompaniment or sequel of acute spreading gangrene, and may occur in cellulitis and cancrum

oris. Frequently the individual attacked is already in a debilitated condition and the inherent germicidal activity of the tissues thus insufficient to cope with the inroads of the infection.

The **Local Changes** at the site of inoculation may take the form of an acute lymphangitis, some type of cellulitis or spreading suppuration, or even an acute spreading gangrene. In virulent types local symptoms may be absent.

The **General Symptoms** are those of fever, often ushered in by a distinct and severe rigor; the temperature reaches 104° or 105° F. and usually remains high, with but slight remissions and no intermissions. Malaise is present, with loss of appetite, and the tongue is brown and parched. The pulse is quick and feeble, the heart-sounds are weak, and the heart itself dilated. The skin has often a slight icteric tinge, and petechiæ may be present. Diarrhœa usually ensues, and the fæces may be blood-stained, whilst the urine is albuminous and contains blood. The patient may, after a period of delirium, become comatose, and die. Dyspnœa sometimes precedes such fatal issue, whilst the temperature may be exceedingly high, or occasionally subnormal; the association of a low temperature with a very rapid pulse is always of grave import. Leucocytosis is usually present and well marked in the earlier stages, but is absent in the worst cases and towards a fatal issue; even under these circumstances there is a relative increase in the number of polymorphonuclears.

When a case takes a more favourable course after the local focus of infection has been effectively dealt with, and perhaps suitable serum and vaccine treatment adopted, the temperature falls gradually, and the patient slowly returns to health.

Diagnosis.—It is sometimes a matter of considerable difficulty to differentiate cases of septicæmia from those of some of the more virulent forms of the acute exanthemata before the characteristic appearances of the latter are manifested. Acute toxæmia is always associated with some focus of infection, but may be so severe as to cause grave anxiety for a time as to whether or not septicæmia is present. If, however, it is possible to open up and drain the infected area, the rapid disappearance of the fever indicates that the cause was probably merely a local, and not the more serious general, affection. A blood examination by cultural methods (see p. 33) may assist in clearing up the diagnosis. From pyæmia, septicæmia is differentiated by the absence of repeated rigors and secondary abscesses.

The **Prognosis** of acute septicæmia is always very grave, especially when due to hæmolytic streptococci (chiefly *Streptococcus pyogenes*).

The **Treatment** of such cases in which the infecting organism is a **hæmolytic streptococcus,** *i.e.* belongs to the *Streptococcus pyogenes* group, has been revolutionized by the recent discovery and use of drugs of the sulphonamide group. Other forms of chemotherapy, such as mercurochrome, eusol, quinine, etc., are useless and may be harmful, as they interfere with the phagocytic activity of the leucocytes. Treatment will further consist in dealing immediately and actively with any local focus of inflammation, either by free incisions and drainage, hot baths, or amputation if such seems desirable.

General measures vary with the patient and the symptoms, but as a rule sufficient easily digested food and ample fluids are required, together with abundance of fresh air, and sleep must be secured by opium or other hypnotics. Antistreptococcal serum given intravenously in doses of perhaps 50 c.c., repeated daily or oftener, for the first few days may be helpful. Vaccines may also be employed, but it is probable that better results will be secured by the use of immuno-transfusion (see p. 10). Favourable results have also been recorded from the intravenous transfusion of normal human blood in cases of septicæmia, pyæmia, empyema, and puerperal infections, amounts of blood from 150 to 300 c.c. being found as efficacious as larger amounts, and equally beneficial are 10 per cent. glucose solution, *e.g.* 3,000 or 4,000 c.c. daily, administered continuously by the drip method through a cannula into the internal saphenous or other suitable vein.

A more **chronic** variety of **septicæmia** is also recognized, which may last for weeks or months. This is often a subacute ulcerative endocarditis, usually due to some non-hæmolytic type of streptococcus, *e.g. Str. viridans.* The history may commence with some localized inflammatory trouble from which the patient has never properly recovered. The temperature becomes of the hectic type, running up 3° or 4° every night, and the fever is associated with profuse nocturnal sweats. Bacteria may be demonstrated in the blood at times. The probable cause is the persistent absorption of organisms into the blood-stream from some localized source of infection, *e.g.* a hepatic abscess or a suppurating gall-bladder or appendix, urinary bladder or prostate, focal infections of tonsils, nasal sinuses, teeth, or pyorrhœa alveolaris. The patient's health and strength are gradually lost, and, unless the local focus can be reached and dealt with, death is likely to result. Surgical interference, though dangerous in these debilitated patients, may be essential in order to attack the cause of the mischief. Along with this, vaccine treatment must also be relied on, together with such measures as shall build up the general health and improve the resistance of the blood and tissues.

VII. Pyæmia.

Pyæmia is a disease characterized by intermittent fever, associated with the formation of multiple abscesses in different parts of the body, arising from the diffusion of pyogenic material, such as infected blood-clot, from some area of local infection.

Bacteriology.—Any pyogenic organism may cause pyæmia, the organism most commonly found being *Streptococcus pyogenes*; but in some cases, especially associated with suppurative lesions of bone, *Staphylococcus aureus* occurs. Less commonly, other organisms are found, pneumococcus (*Streptococcus pneumoniæ*), gonococcus (*Neisseria gonorrhœæ*, or Bacillus typhosus or paratyphosus (*Bacterium typhosum* or *paratyphosum*) and, in acute glanders in man, the production of pyæmic abscesses, due to Bacillus mallei (*Pfeifferella mallei*), is a characteristic feature of the disease.

Pyæmia will not follow the mere entrance of any of the organisms into the circulation, because these will either be dealt with by the leucocytes or else give rise to a septicæmia by their spread. For the development of abscesses it is necessary for the bacteria injected to be mixed with material or aggregated into masses such that the organisms are carried on particles too large to pass through the terminal arterioles and capillaries; abscesses are likely to develop wherever they lodge.

The **Cause** of pyæmia may be stated to be any condition which leads to the formation and detachment of infective emboli in the circulation, such conditions occurring mainly in the veins from disintegration of a thrombus (infective phlebitis) (Fig. 22). The commonest source of this trouble is probably seen in connection with phlebitis of varicose veins, but inflammation of any of the intracranial venous sinuses arising secondarily from diseased bone or spreading in from the exterior may result in pyæmia, *e.g.* in middle-ear disease, which may produce thrombosis of the transverse (O.T. lateral) sinus. The presence of large open-mouthed veins in the puerperal uterus favours the onset of the disease after parturition if infective material is present in their vicinity. Acute infective inflammation of the cancellous tissue of bones very commonly leads to the production of pyæmia, owing to the veins being abundant and thin-walled, and to the considerable tension present from the unyielding condition of the surrounding bony structures.

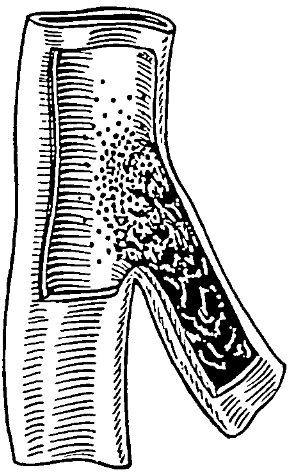


FIG. 22.— DISINTEGRATING CLOT LYING IN A VEIN IN A CASE OF PYÆMIA.

The apex of the clot projects into a larger trunk, and from this clot infected emboli are easily detached into the circulating blood.

When an infective embolus lodges in and blocks a vessel in any region of the body a thrombus forms, and in this the micro-organisms may rapidly develop, the vessel-wall is destroyed, and they spread into the surrounding tissues, causing inflammation, which is likely to end in suppuration. In the lung many such foci may occur, distributed mainly along the posterior border and near the surface; each is sharply limited to a wedge-shaped area of tissue, with the base directed towards the periphery. It is at first reddish in colour from effusion of blood (a **hæmorrhagic infarct**), but soon softens and becomes greyish-yellow from the formation of pus. These abscesses are usually small, and rarely give rise to any physical signs. Similar collections of pus, preceded or not by infarction, may be found in various organs of the body. The lungs, acting as a filter to emboli derived from the systemic veins, are naturally the first organs to be affected, and from the abscesses formed therein spread to the pleural cavity and empyema usually results. Infection of the arterial system, by way of the pulmonary veins and left side of the heart, may then take place, resulting in fresh

suppurative foci in the liver, spleen, kidneys, brain, and in or around bones and joints, etc. If, however, the causal phlebitis is situated in the portal area, the emboli become lodged primarily in the liver, giving rise to acute suppurative inflammation of the portal vein (**pylephlebitis**). When the emboli are many in number, the symptoms are severe, constituting **acute pyæmia**; this is sometimes associated with the presence of micro-organisms in the blood, producing **pyo-septicæmia,** the patient perhaps dying before the secondary abscesses have fully developed. In other cases the general symptoms are due rather to the absorption of toxins from the local foci than to the organisms in the blood.

Clinical History.—The most marked symptom indicating the onset of **Acute Pyæmia** is the occurrence of a severe rigor, which is repeated with a sort of irregular periodicity, *e.g.* at intervals of about twenty-four to forty-eight hours, somewhat simulating an attack of ague. The rigors do not differ from those occurring in other diseases, but they are very severe, and usually followed by profuse sweating. Between the rigors the temperature may fall to normal, but more commonly remains above it. The skin is hot and soon develops an earthy or dull yellow tint, together with erythematous or petechial patches. A sweet, mawkish, hay-like smell of the breath is very characteristic. Grave prostration supervenes, and the patient rapidly wastes. The pulse becomes soft and weak, the excretions are diminished, and a certain amount of nocturnal delirium is noticed, but not necessarily loss of consciousness. The presence of a bruit in the precordial region may suggest the existence of an infective and ulcerative endocarditis, which is not very uncommon. The condition of the tongue varies, but is often red with very prominent papillæ, and becomes dry and brownish.

Towards the end of the first week secondary abscesses appear; they are sometimes unaccompanied by local pain or tenderness and form very rapidly. Joints are not infrequently involved, and may fill with pus, with little or no pain; unless treated early, rapid disorganization and dislocation may follow. The effusion may be puriform, or thin and viscid; it is always, however, swarming with organisms. In the viscera the abscesses are as a rule small and numerous; if they occur in vital organs, such as the heart or brain, death may result from their local development. They are characterized, at first, by the almost total absence of a barrier of granulation tissue, and hence, even when opened early and aseptically, are likely to extend and continue to form pus, instead of following the usual course of rapid repair which succeeds the aseptic opening of an ordinary acute abscess. Any of the serous sacs, and the meninges, are apt to become involved, and widespread suppuration occur in them.

Not uncommonly in these cases painful patches occur here and there in the subcutaneous tissues, accompanied by hyperæmia, which fades away after a few days. These are probably due to the presence of small infective emboli, which the patient has sufficient vitality to overcome without suppuration.

In **Chronic Pyæmia** the febrile symptoms are much less marked;

the abscesses may be few in number, and not of immediate danger to life unless forming in important structures.

The condition of an external wound which has given rise to pyæmia may show the following characteristics. It gapes open and presents an indolent, dry, glazed surface, lacking in the production of the layer of healthy granulations which, on account of the germicidal power of its constituent cells, should form a barrier against the diffusion of the organisms, any newly-formed scar-tissue actually produced tending to break down. If the disease arises in connection with bone, the latter structure may be seen lying bare at the bottom of the wound, denuded of its periosteum, and the cancelli filled with sloughy, fœtid and disintegrating marrow and pus. In cases of bronchiectatic and other varieties of lung abscess, secondary abscesses analogous to those of a pyæmia are of not uncommon occurrence in the brain.

Pathological Anatomy.—The veins leading from the infected area are usually in a state of phlebitis; the coats are thickened, and the lumen is filled with soft, pale, disintegrating clot, which may extend for a considerable distance; the tissues surrounding the vein are also involved in the suppurative process (periphlebitis). Secondary abscesses are found in various parts of the body, most frequently in the lungs, and the consecutive stages in their formation can be clearly demonstrated, from the embolic colonies of bacteria, usually micrococci, through the stage of hæmorrhagic infarction to the complete abscess. The general signs common to all cases of death from toxæmia (p. 65) will also be manifest.

The **Diagnosis** of pyæmia should not be difficult in the majority of cases; but, when it originates without any obvious external wound from a deep-seated focus, or if the importance of some local lesion has not been appreciated, the initial symptoms may be mistaken for those of acute rheumatism, malaria or pyelitis.

The **Prognosis** depends upon the inherent vitality of the patient and the virulence of the disease. In acute cases it is extremely grave, probably terminating in a week or ten days, whilst in the chronic type recovery is not only possible, but even probable, if the local abscesses are favourably situated.

The **Local Treatment** consists in preventing, if possible, the further dissemination of infected emboli and contamination of the general blood-stream. A typical illustration of such treatment, which may be carried out with a prospect of success, is that adopted for infective phlebitis of the transverse (O.T. lateral) sinus complicating disease of the middle ear, where, after tying the internal jugular in the neck, the sinus is exposed, opened, and all the infected clot removed, partly from above, partly from below. Where such treatment is impracticable, all that the surgeon can undertake is, by free incision, to relieve tension in the primary focus and prevent any further or secondary infection by careful attention to asepsis. In some cases amputation will be necessary. The abscesses must be dealt with, when possible, by early opening and drainage, or by aspiration; such wounds often heal well, and joints which have been distended with pus may

recover with free mobility. Aspiration, if practicable, is preferable to incision. Occasionally, however, although asepsis has been maintained, the suppuration continues, and even sloughing of the abscess-wall may follow. If the general condition can be improved, a barrier of granulation tissue will form in time, and repair be established.

The **general** treatment is similar to that for septicæmia (p. 74).

CHAPTER V.

ULCERATION AND GANGRENE.

Ulceration may be defined as the process which gives rise to a loss of continuity in the skin or mucous membrane, due to a gradual necrosis of the tissues, and which results in the formation of a sore or **ulcer.** The dead tissue, which becomes separated from the living during the process, is termed a **slough.**

Necrosis is the term applied to the death and degeneration of a group of cells together with their intercellular tissue. When the process is occasionally limited to the cells, without involving the intercellular tissue, it is called **necrobiosis.** This latter condition is best exemplified in the glandular organs, such as the liver, in which the cells may die as a result of some toxin without disturbing the supporting structure. But, in general, the term 'necrosis' is applied to all types of cell death irrespective of whether the process is limited to individual cells or takes place *en bloc.*

Gangrene is the term applied to tissue necrosis which is accompanied by putrefactive changes. It follows, therefore, that gangrene can never be, strictly speaking, an aseptic process, although the term aseptic is sometimes applied to certain types of gangrene in which the putrefactive phenomena are reduced to a minimum. The factors which control the development of these putrefactive changes are mainly two in number—namely, the presence of organisms and the quantity of fluid within the affected organ at the time of onset of the gangrene. A normal or excess amount of tissue fluid forms a good pabulum for the development of bacteria; hence the dry type of gangrene is usually associated with minimal septic changes and the moist type with the reverse. In the case of the liver, necrosis may remain as such without the development of gangrene for an indefinite period, because it is shut off from contact with putrefactive organisms; but in the case of a limb, the outer covering of which is permeated with saprophytic and other types of organisms, necrosis of any extent is soon followed by the onset of gangrene.

Causes of Ulceration.

The causes of ulceration may be grouped under four headings—mechanical, bacterial, vascular and trophic, and malignant.

Mechanical.

1. Trauma.
2. Thermal agencies.
3. Chemical irritants.
4. Electrical agencies.
5. Radio-active emanations.
6. Prolonged pressure.

Bacterial.

1. Non-specific bacteria.
2. Specific bacteria: tuberculosis, leprosy, syphilis, soft chancre, typhoid, amœbic.
3. Parasitic affections.

Vascular and Trophic.

1. Vascular: Arterial, *e.g.* endarteritis obliterans, embolism. Venous, *e.g.* varicose veins, thrombosis.
2. Trophic: Tabes, syringomyelia, diabetes.

Malignant.

1. Rodent ulcer.
2. Epithelioma.
3. Carcinoma.
4. Sarcoma.

We do not propose in this chapter to deal with all types of ulceration, and those due to malignant disease and specific bacteria will be discussed in the chapters dealing with these subjects. Simple ulceration may be caused by any form of surface irritant, but any of the factors which predispose to inflammation facilitate its development. Faulty nutrition of a part, whether from defective local vascular supply or from long-standing congestion, is particularly liable to further the ulcerative process; thus, in the lower extremity there is a predisposition to its occurrence from, on the one hand, arterial disease which leads to a diminished blood-supply, or, on the other, from the passive congestion due to varicose veins. General debility, such as results from various forms of anæmia, Bright's disease, diabetes, etc., will also favour the occurrence of ulceration. Moreover, when any part becomes anæsthetic, or is cut off from its trophic centres, the continued presence of an irritant may not be appreciated, and hence destructive inflammation occurs, for example corneal ulcer following sensory root section of the fifth nerve: or perforating ulcer of the foot in tabes: hot bottles applied to the feet or elsewhere in old people or in persons suffering from nervous lesions, *e.g.* of the spinal cord or peripheral nerves. Prolonged pressure will also cause ulceration and is the cause of bed-sores. In malignant disease the projection of the mass of the growth may expose it unduly to irritation; but the chief cause of ulceration is the replacement of the deeper layers of the skin or mucous membrane by the cells of the neoplasm, so that, partly from interference with their blood-supply, and partly by their infiltration and destruction by the tumour, when the superficial epithelium wears or sloughs off, it is not reproduced.

Pathology.

The simple type of ulcer tends to pass through three stages from the start to the time when it is healed. These three stages are the following: (1) The stage of ulceration proper or extension; (2) the stage of transition or preparation for healing; (3) the stage of healing or repair. The first stage alone represents the true ulcerative process, although in a larger ulcer the three stages may co-exist.

Stage I.: Ulceration Proper, or Extension.—The special characteristic of this stage is that destructive changes are progressing with greater or less rapidity, and hence the ulcers may be described as inflamed, spreading, or sloughing.

Naked-eye Appearances.—The surface is covered with ashy grey or dirty yellow material, partly slough, partly lymph, partly breaking-down tissue; no granulations are present, the discharge being usually

considerable in amount, thin, serous or slightly sero-purulent, and often irritating and offensive, less frequently purulent. The margins are thickened and inflamed, and the surrounding tissues often œdematous and infiltrated: the edge sharply cut and well defined, and the base of the ulcer thickened and fixed to the underlying structures. In fact, the phenomena are those of an acute spreading superficial inflammation, which terminates in tissue destruction.

Stage II.: The Transition Period is concerned mainly with the separation and removal of sloughs and the preparation for repair. It is a variable stage, which may be short or long, depending on whether the ulcer is running a rapid or slow course, and may persist until after the whole surface is covered with granulations.

Naked-eye Appearances.—When the destructive process has ceased, the surface of the ulcer begins to clean, and becomes, as it were, glazed over; sloughs separate or are absorbed. The discharge becomes less abundant, and the angry red blush is replaced by a rosy hyperæmia. The infiltration of the base diminishes, so that the tissues around are less fixed and more supple. The film on the surface becomes more defined, and in the course of time, shorter or longer according to circumstances, little red vascular spots appear, which gradually increase in number and size, and coalesce, until the whole surface is covered by what has now become granulation tissue. The processes occurring in this stage are: (*a*) the removal of sloughs; (*b*) the covering of the surface with a cellulo-plastic exudate; and (*c*) the vascularization of this, and its conversion into granulation tissue. These do not necessarily go on equally all over the surface at the same time, and thus much variety in its appearance may be manifested.

Stage III., The Process of Repair, follows on the transitional stage. At this time the ulcer is characterized by the following conditions: The surface is smooth and even, shelving gradually from the skin, and covered with healthy granulations; these present a florid red appearance, are painless, and bleed, but not too readily, on being touched. The discharge is merely serous if the surface is kept at rest and free from all irritants; but, should it become infected, or be dressed with irritating antiseptics, ordinary pus is formed. The surrounding skin is soft, flexible, and free from congestion, and the base is similarly free from fixity. The margins present a healing edge, which has been described as manifesting three coloured zones: within is a red area consisting of granulation tissue, covered by a very delicate layer of epithelial cells, which can be seen only in a good light; next comes a thin dusky purple or blue line, where the granulations are covered by a more definite layer of epithelium, and the circulation is becoming retarded owing to cicatricial development; whilst outside is a white zone due to the heaping up of sodden cuticle upon the healthy or healed part.

Clinical Varieties of Ulcers.

The acute ulcer has been described. Other varieties of ulcer are chronic and are the indolent or callous ulcer, the varicose ulcer, and the irritable ulcer.

The Indolent or Callous Ulcer occurs most frequently on the legs of women about the middle period of life. Their chronic character may often be due largely to neglect on the part of the patient, but is also contributed to by the state of general health, and locally by such factors as poor circulation, lack of cleanliness, and the presence of excess scar tissue in the base of the ulcer. The surface is usually smooth and glistening, and of a dirty yellow colour, with perhaps a few badly-formed granulations; the edges are hard and sharply cut, and elevated considerably above the surface, whilst the skin around may be heaped up over the edge, and either covered with sodden cuticle or congested. The skin around is often deeply pigmented from chronic congestion, the pigmentation starting in the separate papillæ as maculæ, which gradually coalesce. The discharge is purulent or serous, and may be so abundant and irritating as to cause eczema of the parts around, and thus give rise to one form of **eczematous ulcer.** The base consists of scar-tissue, more or less abundant according to the age of the lesion, and often extremely dense; it is adherent to the underlying tissues, fasciæ, etc.; and this constitutes one of the main difficulties in healing, as contraction is thereby prevented. If the ulcer is situated over a bone such as the tibia, chronic osteo-periostitis results, and a subperiosteal node is formed, corresponding to the size and situation of the ulcer, forming a mushroom-shaped projection, and possibly going on to necrosis or to diffuse osteo-periostitis. A rarefactive osteitis of the bones of the lower part of the leg, due to interference with the blood-supply, may supervene. These ulcers are sometimes very painful from pressure on cutaneous nerves, and thrombosis not infrequently occurs in both veins and lymphatics of the limb, leading to chronic œdema of the foot, often of a very solid, brawny type, and even to pseudo-elephantiasis. Various deformities of the feet, occurring first as postural contractures, later becoming fixed, are liable to develop in old-standing cases. The supervention of carcinomatous change in these chronic ulcers of the leg is rare.

A somewhat similar condition may also follow large burns or extensive wounds on any part of the body; healing proceeds to a certain extent, and then the contraction of the cicatricial tissue already formed interferes with the vitality of the part still unhealed by compressing the vessels which supply the granulations.

The so-called **Irritable Ulcer** is usually met with in this stage. Its chief peculiarities are the position, generally in the neighbourhood of the ankle, and the pain which accompanies it. The surface of a healing or chronic ulcer can usually be touched without the patient complaining; but in this variety the pain is excessive, especially at night. If a probe is run lightly over the surface of such a sore, one or more spots may be detected as the chief seats of the pain, the rest being insensitive. In all probability, nerve-filaments are there exposed, as the pain has a very marked burning or shooting character.

The **Varicose Ulcer** tends to occur in the leg of a patient with varicose veins, especially when the smaller venules are involved. The skin becomes passively congested, and its nutrition impaired; any

injury or abrasion, which would readily heal in a sound limb, is likely under such circumstances to give rise to a chronic sore. Again, it may be preceded by eczema resulting from the irritation of dirt or the friction of clothes, whilst occasionally it is due to the yielding of the thinned skin which forms the only covering of a much-dilated vein, an accident which may lead to severe hæmorrhage. The characters of a varicose ulcer in the main correspond with those of the indolent variety; it is usually situated on the inner and lower portion of the leg, whilst syphilitic sores are more often placed nearer the knee and on the outer side.

Trophic Ulcers.—These ulcers develop in connection with a disturbance of nutrition of the tissues consecutive to a lesion of the central nervous system. The exact mechanism involved is not properly understood, but it seems to be especially connected with affections of those nerve fibres which pass through the dorsal columns of the spinal cord, and, therefore, these ulcers are seen most commonly in tabes and syringomyelia, but also occur in peripheral neuritis. In diabetes the perforating ulcer which occurs may be due either to a trophic disturbance resulting from a peripheral neuritis, or from associated vascular degenerative changes. As is to be expected, this type of ulcer is very refractive to treatment.

Treatment.—In the early stages treatment resolves itself into removing the cause and protecting the surface from further mechanical irritation. The inflamed part must be kept at rest and elevated, if there is much congestion. The ulcer should be dressed with moist and mild antiseptic applications and, if there is much sepsis, hot fomentations should be employed. When the discharge is very offensive it is better to use a charcoal and linseed-meal poultice.

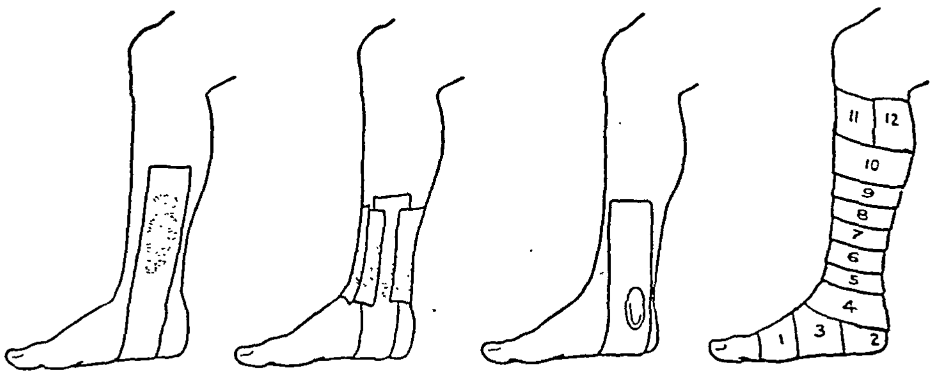
In order to facilitate the healing process it is advisable to avoid too frequent dressings when the acute stage has subsided. Once the wound is mending, the most satisfactory form of treatment is the application of an adhesive elastic bandage. The benefit which follows this method of treatment is derived from two sources—namely, from the continuous pressure exerted, which relieves the congestion of the limb by improving the venous circulation, and the medicated dressing which is incorporated in the adhesive material. Once the bandage is applied it need not be disturbed for one or two weeks. It should be applied with moderate firmness, in the manner illustrated in the accompanying diagram (Fig. 23), and care should be taken to include the foot and ankle. An alternative method of treatment consists of the application of either Unna's paste or zinc and ichthyol ointment. The former has to be melted before it can be used, but in both cases the applications are made as with the adhesive elastic bandage. When the ulcer is complicated by an eczematous eruption soothing applications are required, and for this purpose lead lotion (1 per cent.) is the best when the process is very acute, and liq. carbonis detergens (5 per cent.) may be added to this when the acuteness is subsiding. Later the adhesive bandage may be employed and kept on if no further irritation is produced.

When the ulceration is chronic and the granulations are indolent

more stimulating substances, such as lotio rubra or scarlet-red ointment, should be tried, and the local nutrition of the tissues improved by the judicious employment of ultra-violet or infra-red ray radiation, short-wave diathermy or radiant heat.

When granulations are very prominent they should be lightly touched with caustic, such as silver nitrate or copper sulphate. Very rarely it may be necessary to use the curette to reduce their exuberance.

In very refractory cases operative measures may be necessary. Thus the base of an ulcer, if adherent, may be freed by undermining. At other times it may be possible to excise the ulcer and close the wound either directly or with the aid of a pedicle flap. If this is not possible, grafting by Thiersch's method should be substituted when the surface is clean. This method is of greatest value in the ulceration which results from burns or accidents, but is not likely to be very successful in the chronic varicose ulcer where the surrounding skin is



1. 2. 3. 4.

FIG. 23.—METHOD OF APPLYING ELASTOPLAST IN THE TREATMENT OF CHRONIC INDOLENT OR VARICOSE ULCERS OF THE LEG.

1, Stirrup for large ulcer; 2, stirrup and strips for annular ulcer; 3, stirrup and sponge rubber pad for malleolar ulcer; 4, method of bandaging all ulcers.

impoverished by capillary stagnation. Occasionally amputation of the limb, either on account of pain or continued toxæmia, may be necessary.

In the case of varicose ulceration the principles of treatment enumerated above should be carried out, but, in addition, it is necessary to treat the varicose veins by means of the injection of a sclerosing agent, which will suffice for the ordinary case. When the varicose condition is pronounced and there is an impulse on coughing present in the internal saphenous vein, Trendelenburg's ligature should be applied. This type of ulcer, as a rule, is very amenable to treatment.

Trophic ulceration is difficult to cure, the most important factor consisting in the protection from, and the removal of, surface irritants or pressure. In the perforating variety the condition usually progresses, in spite of all care, and very often amputation may be required in the end. In the case of bed-sores the treatment is mainly prophylactic, and consists of hardening and improving the nourishing of the skin by means of gentle rubbing with surgical spirit. At the

same time care should be taken to protect the skin from soiling by excreta, and by lessening pressure on prominent bony points. When ulceration is present a simple dressing consisting of equal parts of castor oil and zinc ointment seems to be the most satisfactory application to use.

Skin-grafting, or the transplantation of more or less of the thickness of the skin from a healthy to a healing part, was introduced by Reverdin in 1869, and has since been much elaborated, and is employed for large surfaces. The following are the chief methods employed:

1. Transplantation of small pieces of the cuticle and cutis, Reverdin's original plan. A small portion of the cutaneous tissue is pinched up, with or without forceps, and removed by a pair of sharp curved scissors or sharp knife. It should include the cuticle and a portion of the cutis vera, so that a drop or two of blood will slowly ooze from the denuded surface. The graft is gently placed cutis, *i.e.* deep surface, downwards on the surface of the granulations and covered with sterile protective. Many grafts may be applied at the same time, and the whole wound carefully dressed and protected. If there is much discharge, the grafts will not 'take'; but if the surface is healthy, there should be no difficulty in getting them to grow. Usually, for a day or two they become invisible from the cuticle becoming softened or disintegrated; but in reality the epithelial cells persist, singly or in small groups, and from these the epithelium then spreads, soon making itself visible as a distinct centre of repair. This method is not so satisfactory as the following:

2. Transplantation of large portions of cuticle, as suggested by **Thiersch.** This method consists in removing strips of cuticle, up to 4 to 5 cm. square, with a razor, and implanting them on a fresh wound or on a raw surface denuded of granulations by scraping; all hæmorhage must be previously stayed by pressure. In cutting the strips of cuticle care must be taken to make them as thin as possible; the papillæ are always encroached on, however, and hence some amount of blood escapes, in which the grafts are allowed to remain soaking until required for use. The grafts are applied in such a way that they overlap each other and also the margins of the defect. There is always some tendency for the edges to turn in, and this must be prevented by gentle manipulation. They are then dressed with dry sterile gauze, though some surgeons still prefer to keep the grafts covered with protective, or with perforated tin or thin silver-foil. There is usually no need to look at the wound for some days. The inner sides of the thigh and arm are the best places from which to take grafts; the wounds caused by their removal are dressed by sterile gauze over protective or by gauze soaked in tannic acid, and usually heal quickly, if the razor has not encroached on the subcutaneous tissues. The scar which results from the healing of the transplanted grafts is generally soft and supple, and free from the tendency to excessive contraction which marks the ordinary cicatrix.

3. The whole thickness of the skin is used in some instances (**Wolfe graft**). The graft is cut rather larger than is necessary, to allow for shrinkage, and all subcutaneous tissue and fat removed

therefrom. It is applied to the raw surface of the wound after scraping away all granulations, and stitched into position. It may also be applied directly to an operation wound, when the edges cannot be brought together.

The **sieve graft** is in reality a modification of a Wolfe graft and certainly is popular to-day, and is used extensively for covering the extensor surfaces of the hand or foot. After cutting the graft about a quarter of an inch larger than the area to be covered the graft is placed on a swab and several incisions going through the whole thickness of the graft are made (Fig. 24). The graft is then stretched at all parts of its circumference (Fig. 25), and finally the graft is stitched over the raw area (Fig. 26). The openings allow of escape of serum, and so the graft is always in apposition to the tissue beneath it.

4. Unfortunately, the complete detachment of the flap, associated as it is with a complete severance of the blood-supply, is sometimes

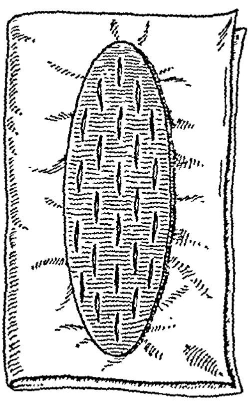


FIG. 24.—INCISIONS MADE INTO SIEVE GRAFT.

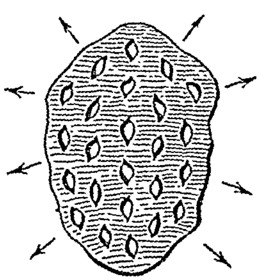


FIG. 25.—SIEVE GRAFT READY FOR TRANSPLANTING.

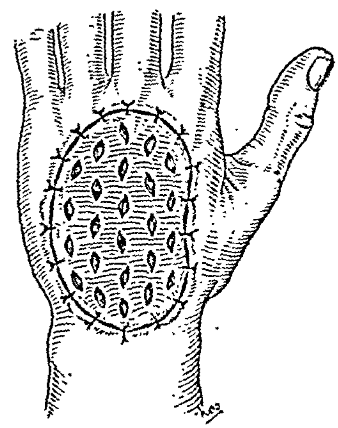


FIG. 26.—SIEVE GRAFT APPLIED TO THE BACK OF THE HAND.

followed by its loss of vitality, and to avoid this accident pedunculated flaps (pedicle-grafting) are now employed not only to cover raw surfaces, but also to build up parts that have been destroyed, as in plastic oro-facial surgery. It is impossible here to discuss this procedure in detail, but as an illustration of its utility may be mentioned the covering of a raw surface after a burn over the front of the elbow-joint, where movement would be much restricted by the development of an ordinary scar. In such a case a pedicled flap should be raised from the lateral abdominal wall and stitched in position to the arm, which is suitably fixed by plaster or bandages to the side; when union has occurred, the pedicle is divided and the arm set free.

To sum up, it may be said that the Thiersch graft is more often cut too thin than too thick. The essentials for success are: asepsis, perfect hæmostasis, perfect application (no turning under of graft edges), immobilization of the graft to the part so that slipping of the graft cannot occur, and the constant application of gentle pressure for

a few days to prevent accumulation of serum or blood under the graft.

The same rules apply to the Wolfe graft, with the added caution that if the graft be subjected to abnormal lateral tension (whether too tight, too loose, or too great pressure applied) it will probably die.

Only autogenous grafts are worth while, or if from another individual preferably one of the same blood-group.

GANGRENE.

The causes of gangrene are similar to those which produce ulceration, but for descriptive purposes modified classification is more convenient. The causes may be grouped under the following four headings:

I. Gangrene from Arterial Occlusion.

1. Arterial disease:
   - (*a*) Degeneration—senile, diabetic.
   - (*b*) Inflammation—endarteritis obliterans (syphilitic), thrombo-angeitis obliterans (Buerger's disease).
2. Arterial spasm:
   - (*a*) Raynaud's disease.
   - (*b*) Cervical rib.
   - (*c*) Ergotism.
3. Embolism and thrombosis.

II. Gangrene from Trauma.

1. Direct:
   - (*a*) Severe crushes or blows.
   - (*b*) Prolonged pressure. Pressure on main artery by tumour, inflammatory exudate, etc.
   - (*c*) Post-operative spreading gangrene.
2. Indirect:
   - (*a*) Ligature or rupture of main artery.

III. Gangrene due to Physical Agencies.

1. Thermal.
2. Chemical.
3. Electrical.
4. Radiation.

IV. Infective Gangrene.

1. Non-specific:
   Boil, carbuncle, cancrum oris, noma, phagedæna.
2. Specific:
   Gas gangrene.

Signs of Local Death.—The onset of gangrene is promoted by the presence of certain alterations which take place in the dead tissues. These are five in number.

1. Loss of pulsation in the vessels.
2. Loss of heat, since no warm blood enters it.
3. Loss of sensation in the dead part, although much pain of a referred type may be experienced whilst its death is occurring.
4. Loss of function of the gangrenous mass, which, if it is a limb, lies flaccid and motionless.
5. Change of colour, the character of which depends on the amount of blood present at the time of death: if the part is full of blood, it becomes purple and mottled; if anæmic, a waxy or cream colour results.

These five signs may be in measure present when gangrene is threatened, as when the vitality of a limb is seriously depressed, as by ligature of the main vessel or by its embolic obstruction; but if they continue for any length of time, death of the tissues will ensue. Sometimes it is difficult to determine whether such a part is actually dead, especially when it is engorged with venous blood and the arterial pulsation has ceased. If living, it will usually be found that pressure causes some modification of the colour, and that the discoloration returns when the pressure is removed.

Pathology.—The character of the changes occurring in the dead tissues depends mainly on the conditions in the tissues at the time of their death and whether or not active putrefaction supervenes.

1. **Dry Gangrene.**—In this form there is **death** and **drying up** or **mummification,** which can occur only when the tissue involved is, previous to its death, more or less drained of its fluids, and where there is free evaporation. The usual cause is chronic arterial obstruction, as brought about by arterio-sclerosis or calcification of the terminal arteries, to which a sudden or gradual complete occlusion of the main trunk is often superadded. The dead part becomes hard, dry, and wrinkled, and is of a dark brown, greenish-brown, or almost black colour from the diffusion of the disintegrated hæmoglobin. The more fleshy parts, *e.g.* above the ankle, rarely undergo perfect mummification, and are often considerably inflamed, and sometimes horribly offensive.

2. **Moist Gangrene** arises when a part of the body full of fluid dies, and is associated especially with conditions which involve venous obstruction as well as a sudden arterial block, *e.g.* in traumatic gangrene due to pressure upon, or rupture of, the main artery. Obviously, if the part affected includes, say, skin-surface or some portion of the alimentary canal, this form of gangrene is likely to supervene.

Where necrosis has occurred in moist tissues, but where the organismal infection is minimal and can still be kept under control, the dead tissues become more or less discoloured, either purple or any shade from black to yellow, green or white. The part remains of much the same size and consistency as at the time of death so long as it is kept from further contamination, and is then gradually cast off from the surrounding tissues without any obvious inflammatory disturbance. The term 'aseptic moist gangrene' is sometimes applied

to this variety, although, as has already been pointed out, its application is not wholly accurate.

When the putrefactive processes are active, the resulting **Putrid Moist Gangrene** is associated with a rapid breaking-up and disintegration of the mass, which becomes black, green, or yellow. The cuticle is raised from the cutis vera by blebs containing stinking serum, or even bubbles of gas, and these can be readily pressed along under the epidermis for some distance. The tissues of the limb are soft and lacerable, and on grasping them emphysematous crackling is usually noted.

The **Later History** of a necrotic or of a gangrenous mass depends upon the nature and degree of the bacterial infection, and also on the bulk of the affected area.

(*a*) If the necrotic area is small in size, and either sterile or only mildly infected, it may, under favourable circumstances, be **entirely absorbed** in the same way as is a catgut ligature. This is often observed after sloughing of small portions of amputation flaps; if the part is kept dry and as aseptic as possible, it is gradually removed, and when the process is completed a small dark scab will separate, and a cicatrix be found beneath it. In a similar way dead bone may be absorbed, if the sequestrum is not too large or too dense, and if it is in close proximity to healthy vascular tissue. The dead portion of tissue is first invaded by phagocytic cells which infiltrate and gradually remove it; granulation tissue replaces it, and this in turn is converted into a cicatrix, and, if at the skin-surface, becomes covered with cuticle in the usual way.

(*b*) If the mass is of such a size or consists of tissues of such a character as to prevent its total absorption, or if the vital activity of the patient is lowered but at the same time the septic processes are reduced to a minimum, a modification of the same process results in **partial absorption** of the dead material, whilst the remainder is separated by a process of ischæmic* ulceration, and, if on a surface, is cast off as a **slough**. The dead part immediately contiguous to the living is removed and replaced by granulation tissue, and this change continues advancing into the mass until the layer of granulations which has penetrated furthest is at such a distance from its nutritive base as to be unable to derive from it sufficient pabulum, owing to the contraction of the cicatricial tissue which is forming behind; and then a simple ulcerative process from defective nutrition causes a **line of cleavage** to form between the living and dead tissues, and by this means the latter are separated from the body. The size of the portion thus cast off is distinctly less than that of the original necrotic mass. This process is associated with local reparative, rather than with active inflammatory, reaction, and but little resulting constitutional disturbance; it is slow in progress, but there are none of the risks attaching to the more rapid septic process. The denser and harder the tissues, the longer they take in separating, and hence, when a whole limb is involved, it is possible for the soft parts to have separated, and the wound caused thereby to have cicatrized before

* Ischæmia = local cutting off of blood-supply.

much impression has been made on the bones. Considerable retraction ensues, giving rise to a 'conical stump,' from the apex of which the bone protrudes.

(*c*) If the necrotic portion is septic, and especially if it be definitely gangrenous, its **separation** is accomplished by inflammatory processes taking place in, and at the expense of, the surrounding living tissues. The extent of the gangrene is primarily indicated by a **line of demarcation,** due to the change in colour occurring in the dead part, the living tissues retaining their normal hue. Apart from any actual septic process also at work, the irritation of the chemical products formed in the dead mass causes inflammatory reaction in the surrounding structures, which ends in suppuration, whilst a layer of granulation tissue forms at the limit of the living portion, and thus the **final line or plane of separation** is produced. Clinically, one notices in this latter stage a bright red line of hyperæmia at the extremity of the living tissues, which gradually spreads and deepens until about the eighth or tenth day, when, if the cuticle is intact, the living and dead parts are separated by a narrow white or yellow line, which is proved, on pricking the epidermis, to be due to the presence of a layer of pus; as the pus escapes, a shallow groove is seen running between a granulating surface on the side of the living tissues and the gangrenous mass. This process, gradually extending through the whole thickness of the limb, is accompanied by the local signs of inflammation, and by fever, the degree of the latter depending on the amount of toxic material absorbed. The inflammation, moreover, is not always limited to the line of separation, but may spread upwards along the lymphatics or veins, or in the fascial and muscular planes, until, perhaps, the whole limb is involved in an extensive suppurative process.

The **Constitutional Symptoms** in cases of gangrene may be described under two distinct headings:

(*a*) Those general conditions which predispose to the occurrence of gangrene, and which are mainly of a debilitating character, such as diabetes and nephritis, and other conditions affecting either the composition of the blood or the vitality of the limbs.

(*b*) Those conditions resulting from the presence of the dead tissue and its connection with the body. Various forms of toxæmia result, usually causing a variable degree of fever. Pain, moreover, is frequently a prominent feature in some forms of gangrene, and the patient is liable to become enhausted from this cause.

Little need be said as to the **General Treatment** of gangrene, beyond that the strength of the patient must be maintained by plenty of easily assimilable food, sufficient stimulant, and tonics. Pain and sleeplessness must be combated by the administration of a suitable amount of opium or morphia, if the kidneys are healthy. Diabetes and nephritis require appropriate dietetic and therapeutic measures.

Local Treatment.—In the early stages when gangrene is threatening and not yet definitely established, the surgeon's aim is directed towards **prevention,** and for this chief reliance is placed on improving the circulation and keeping the part warm. The limb is slightly raised

so as to assist the venous return and thereby prevent stasis, thus helping to improve the arterial supply. When it seems likely that an element of spasm is present, the operation of removal of the sympathetic ganglia (ganglionectomy) or section of the rami communicantes are operations of choice. Periarterial sympathectomy has been tried in England and America and found wanting. It has been shown by Kuntz and others that the sympathetic supply to arterial trunks enters the sheaths at more than one point during their course. By no means do they all enter the sheaths high up. It is perhaps for this reason that the benefits, when derived from a periarterial sympathectomy, are not lasting. Ganglionectomy is the method of choice and its value is now definitely established, and further reference will be made to it in Chapter XVI. A similar result, it is claimed, can be secured by injecting the periarterial sheath with absolute alcohol, which destroys the plexus. Apart from these methods, hot-air baths may be serviceable, but if these cannot be provided the limb is wrapped in warm, dry, carefully sterilized cotton-wool, and moderate elastic pressure is maintained. Under all circumstances the greatest care is taken to ensure as complete asepsis of the part as possible. If measures such as these fail and gangrene supervenes, **amputation** will be required sooner or later, and the rules that govern the time and level of this procedure will be given in the appropriate sections.

Varieties of Gangrene.

I. Gangrene from Arterial Occlusion.

1. **Arterial Disease** forms the most important cause of this condition and may be considered from the two main aspects of degeneration and inflammation.

(*a*) **Arterial Degeneration** accounts for two important varieties—namely, senile and diabetic gangrene.

Senile Gangrene occurs in elderly people and is the commonest variety met with in civil practice. It is produced by a narrowing of, and loss of elasticity in, the smaller arteries, particularly of the limbs, due to the deposition of calcium salts in the middle coat, which results in the formation of calcareous plaques by means of which the arteries are converted into a series of rigid tubes. At the same time the intima becomes roughened, predisposing to thrombosis, the development of which is also favoured by the low blood-pressure so often present in elderly people. The process is a slow one, but may be precipitated by a slight degree of trauma, such as might be associated with an ingrowing toe-nail, a contusion or even exposure to cold. The gangrene is usually of the dry type.

Symptoms.—Evidences of ischæmia may have been present for some time in the form of cramp and pain in the muscles, which become fatigued rapidly, or of sensations of pins and needles or numbness. The pulsation in the tibials may be so slight as to be scarcely perceptible, and the whole limb is shrivelled, and feels cold and heavy. The skin is often passively congested, and prone to eczema or ulceration. When the gangrene commences as a result of some peripheral lesion, an area

of painful redness is noticed, perhaps progressing to ulceration, and in the centre of this patch a slough forms, which becomes dry and black; the process gradually spreads with a varying degree of inflammation, so that it is sometimes known as '**inflammatory**' **senile gangrene.** Often, however, these inflammatory phenomena are very slight, especially when it results from thrombosis of the main vessels. In these cases death of the part occurs without the supervention of any appreciable degree of local inflammatory phenomena, the toes merely shrivelling up and dying. The inner side of the great-toe is perhaps the commonest situation for this process to start (Fig. 27). It attacks successively the other toes independently, or spreads from one to another. Pain is always a marked feature, and, as the disease spreads, the patient becomes exhausted by its long continuance and by the consequent want of sleep. Septic fever, bed-sores, or the supervention of some cardiac, pulmonary, or renal complication, may hasten a fatal termination.

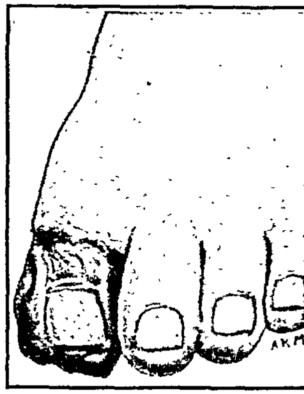


FIG. 27.—SENILE GANGRENE OF THE BIG TOE.

Treatment.—In the earlier stages of malnutrition of a limb from defective arterial supply much may be done to improve the vitality of the part by the cautious use of hot-air baths, massage, etc., and attention to the general health. The patient must be warned of the danger of small injuries, and the possible harm that may follow the injudicious use of hot-water bottles, or of incautiously cutting corns. If the condition progresses and actual gangrene is threatening, ganglionectomy may be undertaken, if it can be proved on X-ray examination that no serious calcareous degeneration of the arterial walls is present.

When gangrene is actually present, treatment is governed by the observation that, after any attempt to amputate through the neighbouring living parts, the gangrenous process is certain to commence again in the flaps; if merely cutting a corn suffices to originate the malady, much more will so severe an injury as an amputation. It is therefore necessary to amputate well away from the dead mass at a point where the blood-supply is sufficient to nourish the flaps, and yet not so near the trunk as to threaten life seriously through shock. *This must be undertaken early, especially when pain is severe,* or if a spreading cellulitis is present. In order to determine the most favourable site, the main artery should be carefully examined, and if feasible the operation performed at a level where it appears not to be occluded. It should also be remembered that the muscles are better supplied with blood than the overlying skin. The condition of the limb will therefore influence the surgeon's decision; if thin, attenuated, and shrivelled, it will be wise to amputate high. The operation should inflict as little damage as possible on the parts, the flaps being nearly equal in length, and sufficiently thick to include plenty of muscle. Where the mischief is limited to the foot, it is usually advisable to amputate through the lower third of the thigh,

or at any rate in the neighbourhood of the knee-joint, though not through the joint itself, as the flaps in that operation are always rather flimsy. If for any reason amputation is contra-indicated, the limb is kept as aseptic as possible, wrapped up warmly, and elevated. The general health is maintained by suitable nourishment, tonics, and stimulants, and pain alleviated by opium or morphia.

Diabetic Gangrene is due primarily to changes in the arterial wall, but may also be favoured by the abnormal condition of the blood and tissues in diabetes, which reduce their power of resisting bacterial invasion, and possibly sometimes by the presence of a peripheral neuritis. Gangrene does not generally occur in the subjects of acute diabetes nor in people under forty years of age. It results usually from some slight traumatic or infective injury, and often commences in a fissure on the underside or at the extremity of one of the toes or on the heel, as a bleb, surrounded by a dusky purple areola. When the bleb is opened or bursts, the central portion of the underlying tissue is found to be necrotic, and from this focus the gangrene spreads. In limbs with some degree of endarteritis, and if the part is kept as aseptic as possible, the dead part may shrivel and dry up (Fig. 28), especially with suitable treatment; but if the necessary local and general precautions are not observed, extensive suppurative infiltration of the soft parts may follow, even though the necrotic process itself be of slight extent, and from this the patient may succumb, the fatal issue being due to septicæmia or toxæmia accompanied by diabetic coma. Not uncommonly the initial foci of the disease may be multiple, or a spreading erysipelatoid condition may develop, and the subcutaneous tissues are sometimes much more extensively involved than the overlying skin.

FIG. 28.—DIABETIC GANGRENE OF FOOT.

Treatment.—In the less severe cases, involving one or more of the toes, it will often suffice to keep the part warm and as aseptic as possible, until it is separated by natural processes, or at any rate the surgeon merely completes the work by dividing or dissecting out bones. Rest is essential with the leg horizontal, as elevation deprives the foot of arterial blood, and depression causes venous congestion of

the limb. Gangrene in itself is not dangerous, but only the infection, and, in early cases, daily gentle irrigation with boric acid or eusol will suffice. If the wound is clean dry sterile dressing should be applied. Dusting powder is not advisable, as it tends to cover up and conceal pus. The diabetic condition, and especially the acidosis, must be treated by dieting, and in suitable cases the administration of insulin and other appropriate measures. Where there is more extensive involvement, the character of the treatment turns largely on the amount of vascular disease and the degree of the accompanying inflammation. If the vessels are tolerably healthy, amputation not very much above the upper limit of the gangrene is justifiable; but usually the main trunks are affected, and a high amputation will be required if the patient's general condition permits. When extensive suppuration is present, it is sometimes wise to lay the parts open and drain away the inflammatory exudate before undertaking radical treatment. The anæsthetic employed must not tend to produce acidosis, and therefore chloroform or the prolonged administration of ether must be avoided. For minor operations local anæsthesia is the method of choice; and, for example, in the case of the lower extremity, if more extensive surgical interference is necessary, spinal anæsthesia should be employed. Preparation for operation and after-treatment should include the administration of sufficient carbohydrates (glucose, barley-sugar, etc.) and fluid, control of the blood-sugar with insulin, the dosage of which is determined by frequent blood-sugar estimations. Where diabetic coma supervenes, insulin should be administered intravenously.

(*b*) **Arterial Inflammation** accounts for two other important varieties —namely, endarteritis obliterans and thrombo-angeitis obliterans (Buerger's disease). The former is due to syphilis, and is characterized by marked proliferation of the intima, which leads to narrowing of the vascular channel, and by fibrosis and thickening of the adventitia, which interferes with the elasticity of the vessel. The condition is not common in the arteries of the limb, although it is the most important cause of coronary and cerebral arterial thrombosis. Thrombo-angeitis obliterans is a similar disease, but differs in that the inflammatory occlusion is accompanied by thrombosis. Both these conditions will be discussed more fully in connection with the chapter on diseases of the arteries. The gangrene is of the dry type, and its clinical characteristics resemble those of the senile variety.

2. **Arterial Spasm.**—Arterial spasm may give rise to gangrene, either as a primary condition in the form of Raynaud's disease, or secondarily to some source of nervous irritation, as is seen in the condition of cervical rib or in ergotism. The condition is usually limited to the ends of the extremities, because it is in the smaller arterioles that the spasm is most pronounced.

(*a*) **Raynaud's Disease** is a condition usually met with in anæmic or neurotic young women between the ages of fifteen and thirty. The cause of the vasomotor spasm is unknown; the only ætiological factor of any note is its occasional occurrence in diseases of the central nervous system, such as syringomyelia and disseminated sclerosis,

and in congenital and tertiary syphilis. Three clinical stages of the attack are described: (1) Local syncope or ischæmia, due to arterial spasm, and characterized by pallor and painfulness of the part. This stage lasts from one to two hours. (2) Local asphyxia, the affected tissues being cyanosed from venous congestion. This stage may last days, weeks or even months, and is followed either by hyperæmia and recovery, or (3) Necrosis and gangrene, the part becoming dry and black. The necrosis is superficial and terminal, and of slow development. Pathologically it is possible to distinguish between three stages of the disease:

(i.) There are no detectable structural changes in the arteries or the soft tissues of the digits. The vessels dilate fully when relaxation

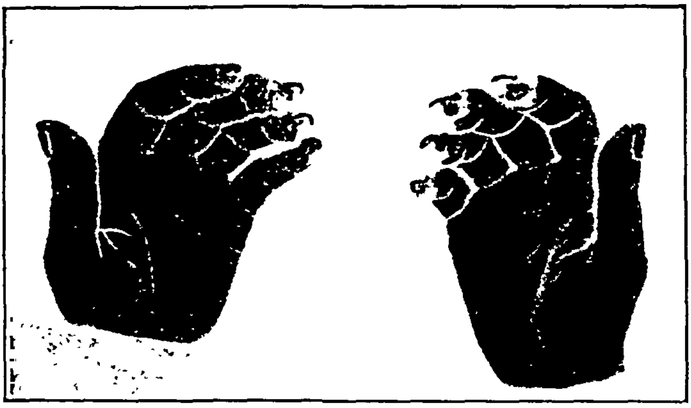


FIG. 29.—RAYNAUD'S DISEASE OF THE HANDS.

is obtained by raising the temperature of the body by applying heat to the lower extremities.

(ii.) There is ulceration of the finger tips or painful stellate scars at the end of slightly tapering fingers. Reflex dilatation to heat is slow and incomplete.

(iii.) There is advanced structural disease of the arteries; fingers fail to heat up when the temperature of the body is raised, and there is a diffuse sclerosis of the digits involving the skin, tendons and joints, giving rise to a sclerodactylia. In some cases there is marked scleroderma. The onset is often sudden, and the disease may last for a variable time; a severe attack would last two to four months. The condition is generally bilateral and affects the fingers (Fig. 29) more frequently than the toes, and occasionally the tips of the ears or nose, but superficial patches may occur on any part of the body; the process is non-febrile and often very painful. Paroxysmal hæmoglobinuria, amblyopia and hemiplegia have all been observed, and have been thought to be due to spasm of the respective arteries, but it is doubtful whether this is the true explanation.

Diagnosis.—The condition often resembles the later stages of a chilblain, but is distinguished by its more dusky colour, the greater pain, the absence of itching, and the fact that the process is not limited

to exposed or terminal parts or to cold weather. The difference in diagnosis between it and Buerger's disease will be given in connection with the chapter on the latter condition.

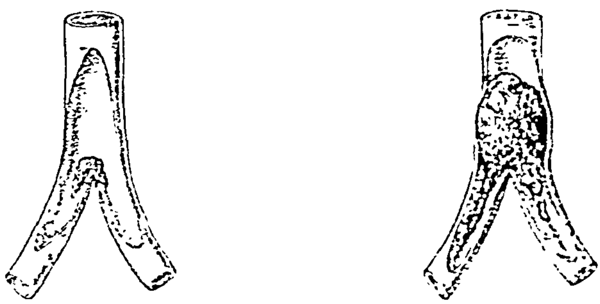
Treatment in the early stages consists in attention to the general health and avoiding undue exposure of the affected parts to cold. Menstrual irregularities and any focal septic lesions, if present, are suitably treated. Local preventive treatment consists in the use of stimulating embrocations or warm douches, but the best results follow the use of electricity. The constant current is employed, and preferably in the form of the electric bath, local or general as required, and repeated either once or several times a day. When actual gangrene is present, the dead tissue should be kept as aseptic as possible, when sooner or later it will be absorbed or separated. Operative treatment consists in sectioning the sympathetic fibres to the limb at some part of their course. Periarterial sympathectomy is no longer practised, as its use was often followed by a relapse, due to the fact that the sympathetic supply to the vessels is given off at various levels during their course. The operation which is most successful in Raynaud's disease affecting the upper limb is a preganglionic resection of the second and third thoracic ganglia and division of the sympathetic chain below the third ganglion. This interrupts the connection between the last cell station and the cord, and is more thorough than a resection of the stellate ganglion. For Raynaud's disease in the lower limb, a lumbar sympathectomy comprising removal of the second, third and fourth ganglia, with the intermediate part of the chain, is the operation of choice. In the first stages of the disease the late results are excellent. In the second stage of the disease there is marked improvement. The hand may become cold again and arterial spasm may return, but the progress of the disease is checked and attacks are less frequent. In the third stage late results are poor, and in a year or two after the operation the condition of the hands is little better than it was before the operation.

(*b*) The syndrome due to **Cervical Rib**, and allied conditions, may occasionally give rise to gangrene of the finger tips which resembles the type just described. It is produced by pressure on the nerve of Kuntz, which passes up from the second dorsal nerve to the lower cord of the brachial plexus. This nerve contains the greater portions of the vasomotor fibres, which results in a reflex spasm of the brachial and other arteries of the upper limb. The gangrene is not due to a compression of the subclavian artery as is sometimes thought. This condition will be discussed more fully in connection with the chapter on orthopædic surgery.

(*c*) **Gangrene from Ergot** is a rare phenomenon in this country, but it has been known to occur when diseased rye has been used in the manufacture of bread. The resulting gangrene may vary in extent, and may lead to the loss of one or more fingers or toes, or, in rare cases, of the greater portion of a limb. In the recent literature there are two instances of gangrene following the therapeutic use of ergotamine tartrate for migraine and thyrotoxicosis respectively. In the first instance three injections were given and in the latter only one, but

gangrene followed very shortly afterwards. Both patients were elderly.

3. **Embolism and Thrombosis.**—The commonest cause of embolic gangrene is probably caused by the detachment from the left auricle of a mural clot which has formed during an attack of auricular fibrillation, but it may also be due to the separation of a vegetation from one of the cardiac valves, or possibly an atheromatous plaque from the aorta or one of its main branches. Thrombosis may occur spontaneously during the course of certain of the specific fevers, such as pneumonia or typhoid fever, or in diseased vessels as happens in Buerger's disease, but it may also follow trauma to the vessel walls. Whether gangrene follows or not depends upon the facility with which the collateral circulation develops, and hence this type of gangrene



A B

FIG. 30.—DIAGRAMS OF EMBOLUS SADDLING THE BIFURCATION OF AN ARTERY

In A the embolus is seen, and the commencement of a thrombus on it, but not yet obstructing the vessel; in B both branches of the trunk are blocked by the increase in size of the clot.

is more common in elderly people in whom the vessels are already narrowed by arterial degeneration.

Emboli are most commonly arrested at the sites of division of the main trunks (Fig. 30, A), or where the calibre is suddenly diminished by the origin of a large branch, the embolus sometimes saddling over the bifurcation, and thus, as it increases in size by the subsequent deposit thereon of blood-platelets and fibrin, effectually closing both branches (Fig. 30, B). In the lower limb it may thus occur at the division of the femoral or popliteal: in the upper, at the origin of the superior profunda, or where the brachial divides.

The chief early **symptom** is sudden severe pain experienced both at the point of impaction and also down the limb along the course of the vessel. Pulsation below the block ceases, the limb becomes cold, useless, and devoid of sensation. If the vessels are healthy, venous stagnation follows, the terminal portion of the limb becoming congested and œdematous, and finally passing into a condition of moist gangrene. If, however, the terminal arteries are calcified or atheromatous, or the heart weak, so that the circulation in the limb is deficient, dry gangrene is likely to follow. The process starts

peripherally, and spreads gradually upwards until it reaches a level where there is sufficient circulation to maintain the vitality of the part (Fig. 31). This usually obtains in the neighbourhood of a joint, since there is always a more free anastomosis here than in the inter-articular portions of the limb; thus, in the leg, the gangrene is likely to be arrested either immediately above the ankle or below the knee.

Treatment.—In the first place the distal portion of the limb must be rendered as aseptic as possible, special care being directed to the intervals between the toes and to the semilunar folds of the nails. If the site of the embolus can be located, and the patient can stand it, the artery may be exposed and incised longitudinally, and the embolus removed (**embolectomy**) with subsequent suture of the vessel. Sufficient numbers of successful cases of this operation have been

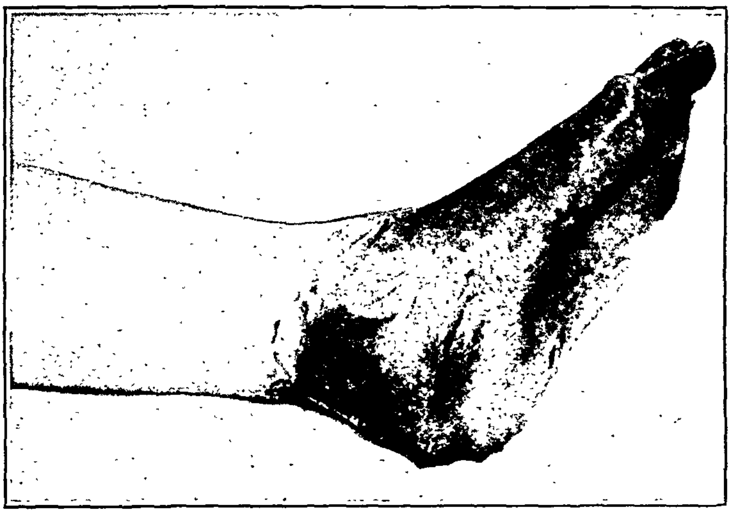


FIG. 31.—EMBOLIC GANGRENE DUE TO EMBOLUS IN POPLITEAL ARTERY.

recorded to prove its value. Failing this, expectant treatment is adopted, and if gangrene occurs amputation must be carried out, but not until a definite line of separation has formed. Precautions as to maintaining as aseptic a condition of the dead part as possible must be observed throughout the course of the case. Should the dead portion become seriously infected, the site of amputation may have to be at a considerably higher level.

II. Traumatic Gangrene.

By traumatic gangrene is meant that variety occurring as the consequence of an injury, whether applied to the main blood-vessels (indirect traumatic gangrene), or directly to the tissues themselves (direct traumatic gangrene).

1. **Direct Traumatic Gangrene,** resulting from the immediate effect of injury to the parts, is similarly due to a variety of lesions.

(*a*) **Severe crushes or blows** are a common cause of this type of gangrene; thus a limb may become mangled between the wheels of

machinery, or by heavy weights falling on it, or by the passage of vehicles over it. Not only are the parts crushed, severely contused, or even 'pulped,' but the blood-vessels may be torn, and the pressure of extravasated blood contributes to the result. The gangrene is of the moist type, and is more likely to supervene in patients whose vitality is diminished. Thus, a crush of the foot in an elderly person is often followed by it, whilst in a young and healthy adult it may be prevented.

Treatment.—If the part is hopelessly damaged, operation should not be delayed, on account of the dangers of infection; and therefore immediate amputation is recommended. The question of shock and its influence in determining operation is discussed elsewhere (p. 270). When there seems a reasonable chance of saving the limb, it is cleansed and purified under the strictest antiseptic precautions; should gangrene supervene, the limb may be removed later.

(*b*) **Prolonged pressure** is also capable of producing gangrene. Gangrene from the pressure of splints or plasters, where use of these is unavoidable and cannot be replaced by other methods of treatment, though occasionally difficult to prevent, is generally the result of carelessness. Thus, when bone fragments are much displaced after a fracture, considerable pressure may be required to retain them in good position, and therefore every precaution must be taken to prevent possible necrosis and gangrene. Should these occur, pain of a neuralgic type is usually felt for a few days, but is not necessarily severe enough to act as a warning of the seriousness of the condition; when the limb is freed later on, the dead portion of the skin is white, anæmic, and insensitive. The necrotic process may extend to some depth, and hence the greatest care must be taken to keep the dead tissues aseptic, thereby avoiding grave disturbance.

Bedsores or decubitus ulcers are likely to occur in patients who are kept for a long time in the recumbent posture, or in any one particular position. The parts most exposed to pressure become red and congested, and finally ulceration or actual gangrene supervenes. Bedsores are not usually extensive or deep unless the patient is debilitated or paralyzed, when the process produces the acute or trophic form of ulcer which may extend rapidly, destroying fasciæ, laying open muscular sheaths, and even leading to necrosis or caries of bone. This variety may fail to respond to any form of treatment. The spinal canal itself has been opened in this way, and death from infective meningitis has resulted. To prevent the occurrence of this and also of the postural or chronic variety of bedsore, the nurse must see that the draw-sheet and bed-linen are placed smoothly, and without creases, and that no contamination by urine or fæces is allowed. The skin of the back is daily washed with some non-irritating soap, and rubbed with a soothing and hardening application, such as methylated alcohol, or painted with an alcoholic solution of picric acid, or with a mixture of alum dissolved in equal parts of water and alcohol applied several times daily. It is then dusted over with a powder, consisting of equal parts of oxide of zinc, boric acid, and starch, in order to harden and dry it. An electric hair drier may often be used with advantage.

If the skin becomes red, it should be painted with a mixture of equal parts of tincture of catechu and liquor plumbi subacetatis, which when dry leaves a powdery film on the surface: and protected from pressure by a water-pillow ring. Treatment with elastoplast at this stage is also well worth tyring in many cases. Paraplegic patients or old people should be placed on a water-bed, which must be sufficiently, but not excessively, distended. If there is too little water, the weight of the body displaces it unduly, and no good results; whilst if there is too

FIG. 32.—POST-OPERATIVE GANGRENE OF THE SKIN FOLLOWING EMPYEMA.

much, the bed becomes hard and resistant, and fails in the object for which it is employed. When an open sore forms, fomentations are required in the more acute stages, whilst later it may be dressed either with tannafax jelly or diluted boric acid ointment, or in the more sluggish cases with resin and boric acid ointments mixed. Compound tincture of benzoin (Friar's balsam), mixed with castor-oil (1 part of the balsam to 7 of the oil), is useful in this condition. When healing is taking place the bedsores may be completely covered with elastoplast.

(*c*) **Gangrene of the skin following operation** sometimes occurs in

cases of suppurative appendicitis and empyema (Fig. 32). The condition remains limited to the skin and subcutaneous tissues, although rarely it may penetrate more deeply. The only effective method of arresting its progressive spread so far discovered appears to be through electro-cauterization of the margins.

2. **Indirect Traumatic Gangrene** may be due to several causes, of which the following are most common:

(*a*) Ligature or rupture of a main artery usually does not produce gangrene in a healthy limb; but should the latter be in a state of chronic malnutrition and deficient blood-supply from preceding arterial disease, death of a certain portion is likely to ensue, the case running a course similar to one of gangrene due to embolus. It is usually of the dry type, and limited to one or two toes, or to a patch of the superficial tissues; but if it reaches the more fleshy portions the moist variety supervenes. Pressure on a main artery by a tumour or inflammatory exudate are rare causes, but are occasionally seen. Gangrene may also be caused by the strangulation of organs, either within the body, as in a strangulated hernia, or outside of it, as when a ligature is tied round the base of the penis, or a tight ring constricts a finger (Fig. 33), or a bandage is applied too tightly round a fractured limb. It may even result from the swelling of a limb under a bandage, which has been originally applied with no undue tension. Collodion dressings contract on drying, and may in some situations interfere with the arterial supply of, say, the point of a finger.

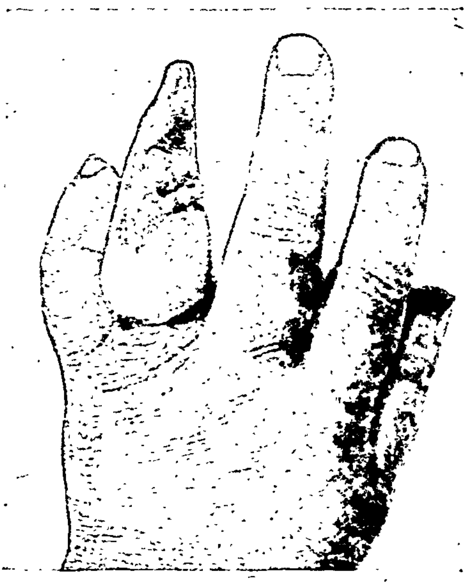


FIG. 33.—GANGRENE OF FINGER DUE TO STRANGULATION BY WEDDING RING.

Treatment.—In cases where it is feared that the nourishment and vitality of the distal parts may be jeopardized, an attempt should be made to reduce the circulation gradually before completing the occlusion of the vessel; time is thus given for the opening up of a sufficient collateral circulation.

If gangrene has actually occurred, the parts must be kept warm and as aseptic as possible until a definite line of separation forms, and then the natural processes at this level are assisted by dividing tendons and bones.

If the parts are hopelessly injured, amputation should be performed at once, so as to prevent the risk of infection. In some fractures and dislocations, with accompanying vascular damage, it may be possible to save the limb by cutting down, turning out clots, and ligaturing the injured vessels, whilst the bony lesion is dealt with in a suitable

manner. The limb should afterwards be elevated slightly, and the peripheral segment kept warm and aseptic. Should gangrene supervene, amputation will be required, its situation depending on the character of the local lesion; if the latter is not of a serious nature, *e.g.* a clean fracture or simple dislocation, it is wise to wait for a line of demarcation; but if comminution of bone or other grave local trouble is present, one should amputate above the injury.

III. Gangrene due to Physical Agencies.

1. Gangrene due to Thermal Agencies.

(*a*) **Frost-bite.**—This condition, not often seen in this country, is by no means uncommon in regions where the winter is colder, and is induced more readily if a high wind is blowing, the heat of the body being thereby quickly lost. Children and old people are more likely to be attacked, as their vital powers are less than those of adults. Imperfect protection against cold whilst flying, especially at high altitudes, is another cause of frost-bite.

FIG. 34.—GANGRENE FROM FROST-BITE.

The condition originates in one of two ways:

(i.) From the direct effect of cold on the tissues, which become shrunken, hard, and of a dull waxy appearance. No pain is experienced in the freezing process, so that onlookers are more likely to recognize the condition than the individual himself. The extremities of the body, where the circulation is sluggish, and exposed parts, such as the nose and ears, are chiefly liable to be attacked. Gradually the part shrivels, turns black, and is either absorbed or separated by a process of ulceration, with or without suppuration. A feature of gangrene from frost-bite is the more extensive implication of the superficial than of the deeper tissues on account of their greater exposure (Fig. 34).

(ii.) From the subsequent inflammation in parts which, though frozen, are not immediately killed. The thawing of these structures is accompanied by severe pain, and the prolonged cessation of the circulation in the affected part so depresses the vitality of the vessel-walls that the readmission of the circulating blood is likely to be followed by an acute inflammation, which terminates in necrosis from compression of the vessels by the rapidly formed exudate. If it

escapes actual death, the part remains red, congested, and painful for some time, and superficial ulcers may develop; eventually, however, it recovers.

Treatment.—The frozen parts must be thawed very gradually, and the blood admitted into the tissues slowly, if inflammatory gangrene is to be avoided. They should be gently rubbed with snow or cold water, and warmed by being held in the hands of the manipulator, whilst the patient should be placed in a cool room, the temperature of which is slowly raised. As reaction comes on, a small amount of warm drink may be cautiously given. Excessive pain or congestive œdema may be limited by elevation of the part. If actual gangrene occurs, the dead tissue must be rendered and kept as aseptic as possible, and the case carefully watched until a definite line of separation has formed.

Indians, lumbermen, prospectors, etc., in North-West Canada, where frost-bites are common, have found that oil of turpentine is the best application in all stages. The parts are kept soaked with the fluid, and the results as reported have been most successful.

(*b*) **Burns and Scalds.**—These may be considered as a special variety of wound, not necessarily ending in gangrene, brought about by the action of heat—**burns,** either by the close proximity to, or direct contact with, flame or heated solid bodies: **scalds,** by the action of boiling water, superheated steam, or other hot fluids or gases—the difference in the effects being comparable to the distinction between roasting and boiling. Naturally, fluids such as oil, which boil at a higher temperature than water, produce correspondingly more severe results.

Six different degrees of burn were described by Dupuytren, and his classification may still be retained, as it is universally known.

The **first** degree consists merely in a scorch or superficial congestion of the skin, without destruction of tissue; the part may for a time remain red, painful, and prone to ulceration. Should the scorch be often repeated, as by people constantly warming their legs before the fire, the skin becomes chronically pigmented and indurated (erythema ab igne).

In the **second** degree the cuticle is raised from the cutis, and a bleb or blister results. When this bursts, and the cuticle is removed, the cutis vera, red and painful, is exposed below. Permanent discoloration may follow this lesion.

In the **third** degree the cuticle is destroyed, as is also part of the cutis vera, but the tips of the interpapillary processes, including the exquisitely sensitive nerve terminals, are laid bare and left intact; consequently this is a most painful form of burn. The deeper structures of the skin, *viz.* the sweat and sebaceous glands, and the hair follicles, are not destroyed, so that, although the surface during the healing process becomes covered with granulations, the integument is very rapidly replaced, since there are so many surviving epithelial elements from which it can grow. The cuticle is able to form, not only from the edge, as must occur wherever the whole of the cutaneous envelope is destroyed, but also from innumerable foci scattered over the wound-surface. The resulting scar, though often white and visible, undergoes no contraction; it is supple and elastic from containing all the elements

of the true skin. Burns due to the sudden generation of heated gases, such as the explosion of shells or bombs, or the bursting and ignition of a petrol-tank, are often of this type, and with careful treatment which conserves any undestroyed portion of epithelium excellent results are often obtained; the face, neck, and hands are usually the parts chiefly involved.

In the **fourth** degree the whole thickness of the integument is destroyed, as well as part of the subcutaneous tissues. In the **fifth** the muscles are also involved, whilst in the **sixth** the whole limb or other affected part is completely charred and disorganized. In the last three forms healing can occur only by removal of sloughs and the formation of a cicatrix, which by its contraction may lead to deformity.

From a practical standpoint it is easier to divide burns into two classes: (1) those which involve partial skin loss (1st and 2nd degree burns) and (2) those which involve total skin loss (3rd degree burns or deeper).

The Clinical Course of Burns may be considered under four stages:

(1) **Initial Shock.**—This is uncommon, but if it does occur its intensity depends as much on the extent of the burn as on its depth, so that total scarring of a limb may cause less depression of the system than an extensive scorch, especially if the latter involves the abdomen or the head and neck. Initial shock results from a severe vasomotor upset initiated by the reception of multiple painful impulses from the injured area. It resembles a fainting attack. The clinical picture is fairly constant; there is a fall in blood pressure, the temperature is subnormal, and the pulse is feeble but its rate is usually unaltered.

As would be expected, death from initial shock due to burns is rare.

(2) **Secondary Shock** may be an extension of the initial shock or occur after an interval, and it is the cause of 60 to 70 per cent. of all deaths from burns.

It has now been definitely proved that secondary shock is a condition of circulatory failure due to loss of circulating blood in the circulation. There is an abnormal permeability of the walls of the small blood-vessels due to the injury of the burn and plasma escapes into the tissue spaces and from the surface of the burnt area. This excessive permeability may persist up to forty-eight hours and causes a great reduction in the volume of the circulating blood, while hæmoconcentration becomes marked. The result of the changes is dangerous to the patient as there is a definite oxygen want in the vital centres of the brain and therefore treatment must be prompt if life is to be saved.

Clinically secondary shock is a more marked picture of initial shock, only the blood pressure is lower.

As a rule the greater the hæmoconcentration the worse the prognosis. Hæmoconcentration is probably the best criterion of the presence of secondary shock.

(3) **Acute Toxæmia.**—This is a condition of septic intoxication which tends to occur from forty-eight hours to ten days after the

injury, and is the result of absorption of injured cells and tissues in the region of the burn. This process of septic absorption as it progresses floods the circulation with its products, which when they reach the liver cause some necrosis of the liver cells. Should some bacterial invasion into the burnt area also take place the degree of toxæmia becomes much more marked. The clinical picture consists of a distressed and irritable patient with a high temperature, rapid pulse and complaining of headache and anorexia. Vomiting is quite common. By the time such symptoms have developed the actual burnt area is obviously septic and exudes sero-pus. This state of affairs should not be seen at the present day, for it can be prevented by prompt and adequate treatment. Once the toxæmia has gained a foothold it is difficult to eradicate, and if sepsis is well marked septicæmia and pyæmia may supervene. Duodenal ulceration is a rare complication of infected burns, and it was not met with in the navy in the first World War, when over a thousand cases of grossly infected burns were treated in the naval hospital and hospital ships.

(4) **Healing of** burns should be complete without scarring or deformity.

As a rule burns appear to take longer to heal than raw surfaces of similar extent resulting from mechanical violence. Sepsis is the commonest cause of scarring with contracture and should be eliminated by efficient treatment.

Large whole-thickness skin burns require skin grafting if scarring is to be prevented.

Causes of Death from Burns.—If an individual is burnt to death, the fatal event is usually occasioned by asphyxia from the smoke and noxious fumes of the fire, or by shock and syncope. If death occurs within the next few days it results from secondary shock due to loss of plasma into the tissue fluids and from the surface of the burnt area. A fatal issue may also result from infection, the terminal event being bronchopneumonia. At a later stage still, general exhaustion with nephritis may be the cause of death. The prognosis in children is always more unfavourable than in adults.

Treatment.—In the treatment of burns first aid is of primary importance. Pain should be alleviated at once by morphia; for an adult $\frac{1}{3}$ gr. to $\frac{1}{2}$ gr. should be given, depending on the severity of the pain. *Morphia will never kill a patient who is suffering from pain.* In small children up to six months tinct. opii ♏$\frac{1}{4}$ to ♏$\frac{3}{4}$ should be given, while at the age of one year three minims of tincture of opium can be given.

Once pain is relieved other methods for preventing or reducing shock should be instituted without delay. Warmth is essential and any local treatment should be painless and prevent any loss of plasma from the burnt surface; it should also prevent the development of sepsis and help to promote rapid healing.

For minor burns one of the many excellent burn jellies, gentian violet, triple dye, amertan, or dettol burn jelly, can be applied and will give very satisfactory results.

The actual burnt area should be cleansed under gas-and-oxygen anæsthesia, the blisters and dead epithelium removed and the whole area swabbed with warm normal saline. The wound is then dried and the jelly liberally applied on a layer of gauze and retained in place by a bandage. The whole dressing can remain undisturbed until the twelfth day, when the tan will probably have separated.

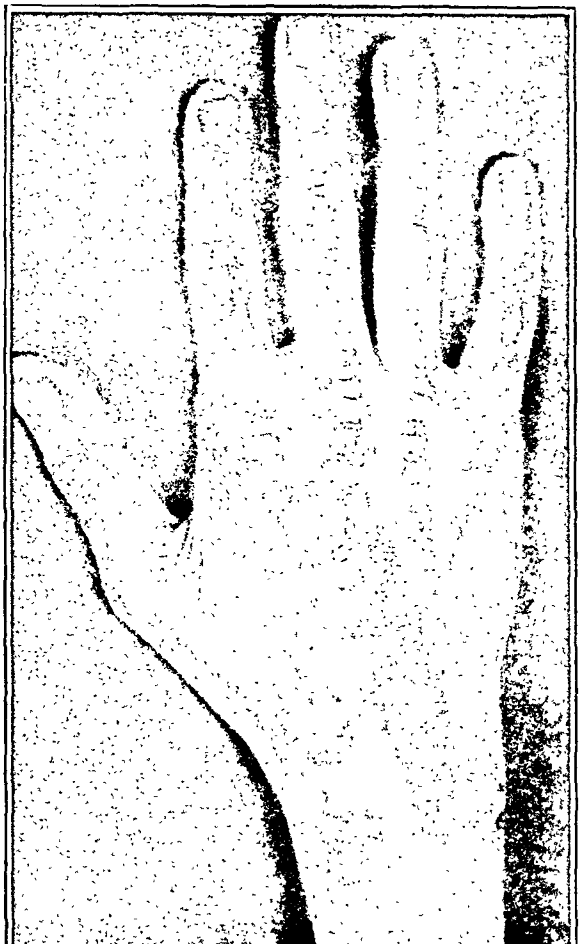


FIG. 35.—LATE SCARRING FROM BURN OF HAND.
Prompt skin grafting would have prevented this.

For the more severe or major burns the treatment of shock will require prompt treatment and the sooner the patient is taken to hospital the better. No local treatment to the burn should be given until the patient reaches hospital, the burnt area being simply covered with a clean towel. The patient, after receiving an adequate dose of morphia, is kept warm under a shock cradle while a hæmoglobin estimation is carried out. For practical purposes we can assume that a normal hæmoglobin of 100 per cent. is associated with a blood

volume of 5 litres, of which 3 litres are plasma. Any hæmoconcentration can be estimated from the following table:

Hgb. per Cent. Haldane.	*Blood Volume (litres).*	*Plasma Volume (litres).*	*Estimated Deficit in Plasma Volume (c.c.).*
100	5·0	3·0	—
105	4·75	2·75	250
110	4·55	2·55	450
115	4·35	2·35	650
120	4.15	2·15	850
125	4·0	2·0	1,000
130	3·85	1·85	1,150
135	3·7	1·7	1,300
140	3·55	1·55	1,450
145	3·45	1·45	1,550
150	3·35	1·35	1,650

Whole-blood transfusion is contraindicated because of the hæmoconcentration and the capillaries would become blocked with red blood corpuscles. Saline and gum saline solutions if given intravenously would only cause a serious drop in the concentration of the plasma proteins and therefore should be avoided.

Hæmoglobin estimation can be quickly and easily carried out and the estimated amount of plasma required can be given. In severe burns it is better to give over the estimated amount rather than below it. It may be necessary to give three or four plasma transfusions.

Reconstituted dried serum can be given in place of plasma if the latter is not available.

Dried serum is supplied in screw-capped bottles each containing the dried products of 200 c.c. or 400 c.c. human serum.

To give the reconstituted serum, 100 c.c. of distilled water is added to a bottle of dried serum under strict aseptic precautions and the bottle agitated to ensure complete solution of the serum. The temperature of the solution should be brought up to 95° F. by standing the bottle in a basin of warm water.

The serum should be given intravenously by means of a 20 c.c. glass syringe fitted with a two-way stop-cock.

Other measures to combat shock may be necessary. Warmth may be given by means of a shock cradle, and warm sweetened drinks by mouth should, if possible, be given.

In some cases oxygen is essential and may be given by means of an oxygen tent, or, if high concentrations are necessary, a B.L.B. inhalation apparatus should be used. Concentrations of 90 per cent. oxygen can be obtained by the use of the B.L.B. mask (Fig. 36). When once shock has been overcome, then and only then can the local condition be treated.

The patient should be taken to the operating theatre and anæsthetized with gas and oxygen. The whole burnt area should be thoroughly cleansed, and all raised and dead skin should be removed. The area is then swabbed with saline and dried by means of an electric

hair drier. Some 1 per cent. gentian violet is then applied by means of swabs and then the area is dried once more. Instead of gentian violet triple dye may be used (equal parts of gentian violet 2 per cent., brilliant green 1 per cent., and neutral acriflavine 0·1 per cent.) and gives equally good results. Two applications of 20 per cent. tannic acid or 10 per cent. silver nitrate are then given and the area again dried. After good tanning has taken place the patient is returned to the ward and nursed under a shock cradle. Any cracks in the coagulum are painted with some gentian violet 1 per cent. (Fig. 37).

If any soiling of the tan with urine or faeces should occur, careful

FIG. 36.—PATIENT WITH BURNS OF CHEST AND ABDOMEN RECEIVING HIGH CONCENTRATION OF OXYGEN FROM B.L.B. MASK.

cleansing with 10 per cent. dettol should be undertaken. The area should be dried and then 1 per cent. gentian violet applied.

The tan will commence to separate after fourteen or fifteen days, and on removal complete healing will have occurred in the partial skin loss burns. For those burns in which there is complete skin loss, a granulating area will be found under the tan, which requires skin grafting (Fig. 38). For burns of the hands it is essential that tannic acid should not be used because there is a great tendency for the tan to contract and cause terminal necrosis of the phalanges.

Saline baths are very soothing for burns of the hands, and the patient can be encouraged to move his fingers while in the bath. Two or three baths of an hour each should be given daily. After each bath the burnt area is dried and dusted with sulphonamide powder

and then covered with *tulle gras* (*tulle gras* may be prepared by using curtain net with a mesh of 2 mm. Six-inch squares are placed in a tin box of slightly larger size with greaseproof paper between each square of material. The box is then filled with the following

FIG. 37.—EXTENSIVE BURN OF BOTH BUTTOCKS TREATED WITH TANNIC ACID.

mixture: soft paraffin 98 gm., balsam of Peru 2 gm., sufficient to impregnate and cover the material completely after sterilization) or some similar preparation (Jelonet). Several layers of gauze soaked

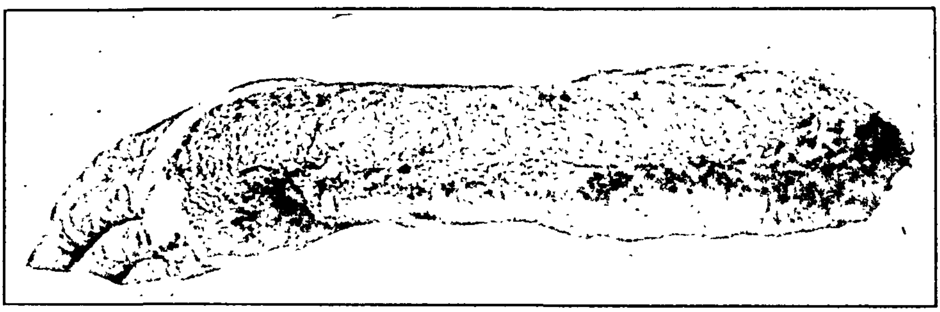


FIG. 38.—LARGE WHOLE THICKNESS BURN OF FOREARM TREATED WITH TRIPLE DYE.
The granulating area just prior to skin grafting.

in warm saline complete the dressing. The saline packs are replaced every three hours without disturbing the *tulle gras*.

An alternative treatment is to encase the hand in plaster-of-Paris splint after applying sulphonamide powder and vaseline gauze. The fingers are left free under the plaster so that movement can take place. Triple dye jelly can be used for the hands and has not the

disadvantages of tannic acid. The envelope method of Bunyan is useful for septic burns of the extremities. This treatment consists in the application of a coated-silk envelope to the burnt limb (Fig. 39) and irrigation with 2 per cent. electrolytic hypochlorite twice a day. This method is painless and very rapidly clears up the sepsis, and is useful for whole-thickness skin burns.

Whatever form of treatment is carried out for burns it does not take the place of skin grafting when granulation tissue has formed in a whole-thickness skin burn.

Burns of the face can be treated with saline followed by triple dye (Fig. 40B), or, if preferred, sulphonamide powder and *tulle gras*

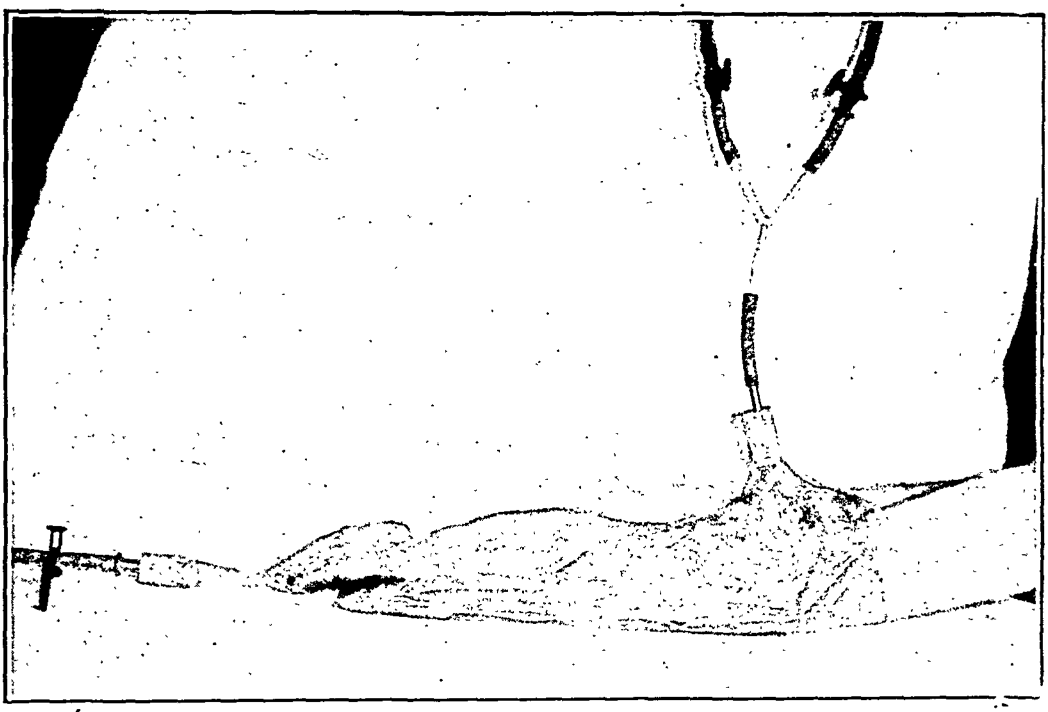


FIG. 39.—BURN OF FOREARM AND HAND TREATED WITH BUNYAN'S BAG OR ENVELOPE.

can take the place of the triple dye. Both treatments give good results.

The after-treatment of burns is very important, yet it is apt to be neglected. Lanoline should be rubbed into the healed burnt area each night for fully a month. The massage promotes good circulation and thus the skin area will eventually have a better blood supply. Lymphatic drainage is also improved by this form of after-treatment. If the hands are so treated, cotton gloves can be worn in order that there is no unnecessary soiling of the bed linen. If the feet and legs are being treated thin stockings can be worn at night to prevent the bedclothes from being soiled.

Superficial X-ray therapy should play an important part in the after-treatment of extensive burns. If there is any suggestion of

keloid scar formation this form of treatment should be adopted at once. Even in cases where skin grafting has been performed there is a danger of excessive formation of collagen between the grafts, and X-ray treatment should be given in order that a nice smooth surface will eventually result.

In those keloid cases which are seen late X-ray treatment should be tried, and if the result is not satisfactory complete excision should be performed followed by skin grafting. When healing has taken place in eight or nine days, another X-ray application should be given in order to prevent a recurrence of the keloid. A month later a final X-ray treatment should be given. With such a procedure

FIG. 40A.—EXTENSIVE BURN THREE HOURS AFTER INJURY.

FIG. 40B.—SAME CASE FIFTEEN DAYS LATER AFTER TREATMENT WITH SALINE AND TRIPLE DYE.

excellent results are obtained in what were often thought to be hopeless cases.

2. Gangrene due to Chemical Agencies.

The action of **corrosive** or **caustic** chemical is followed by a localized traumatic necrosis, the degree of which varies with the amount and character of the irritant present, and the duration of its action. All that is needed is to keep the parts aseptic, and allow them to be absorbed or separated by natural processes.

Such necrosis occasionally follows the application of a carbolic acid compress, even when weak solutions, *e.g.* 1 in 60, are employed. The fingers are the parts usually affected, and the necrosis does not seem to be due to tight bandaging, or to the presence of a waterproof covering. Carbolic acid is readily absorbed through the skin, and possibly acts by directly poisoning the tissues.

3. **Gangrene due to Electrical Agencies.**

This will be considered in the Chapter on War Surgery (LI).

4. **Gangrene due to the Effects of Radiation.**

Many types of radiation will lead to necrosis of tissues. When these have been employed therapeutically the necrosis is always the result of over-exposure, and hence is not often seen nowadays. The most serious variety is that which follows radium treatment because it is penetrating, very often causing necrosis of bone, and taking several months or years to heal. In some cases it is followed by the development of carcinoma in the scar. Necrosis may also follow treatment by X-rays, ultra-violet and infra-red radiation and artificial sunlight, but is usually less severe and of shorter duration than the type due to effects of radium. In the early stages a painful erythema develops, which may be succeeded by blister formation and later by ulceration. The latter often spreads deeply and widely, and may lead to the death of the patient from exhaustion or toxæmia. The whole process, particularly after radium, is very slow and may be very painful; but once the healing process has commenced recovery may be hastened by the judicious employment of skin grafting. But early plastic repair of the defect is not as a rule successful.

IV. **Infective Gangrene.**

Infective Gangrene may be of two types, specific and non-specific. The latter variety is commonly due to non-specific organisms, in particular the pyogenic group, and is manifested in such conditions as boils, carbuncles, phagedena, noma and cancrum oris. Boils and carbuncles will be described in connection with the chapter on surgical diseases of the skin, and reference will be made to phagedena in the chapter dealing with syphilis. Cancrum oris and noma will be dealt with below. The specific variety of infective gangrene is due to a particular group of anaërobic organisms and is referred to as acute spreading, acute emphysematous or gas gangrene, and is one of the most rapidly fatal diseases met with in surgery.

Gas Gangrene (Acute Spreading or Acute Emphysematous Gangrene).— This disease is one of the most rapidly fatal met with in surgery.

The individual attacked is often debilitated, *e.g.* as a result of the hardships of military service, or from alcoholic excess, or from malnutrition; but even healthy individuals may be attacked if the infective agent is active. It is sometimes seen in diabetics, but a non-diabetic toxic glycosuria occasionally develops in the course of the disease itself.

The causal lesion is usually severe, such as a compound fracture or dislocation, especially if the soft parts, and particularly the muscles, are much contused or very dirty. Defective purification of such tissues, and injudicious attempts to save them by accurate and close stitching, perhaps without drainage, are amongst the most frequent predisposing causes of this complication. Less commonly it follows a small and insignificant prick, scratch, or abrasion, through which

a highly virulent organism gains access to the tissues. Its most frequent occurrence was in connection with wounds received during the Great War, the majority of which took place on highly fertilized soil.

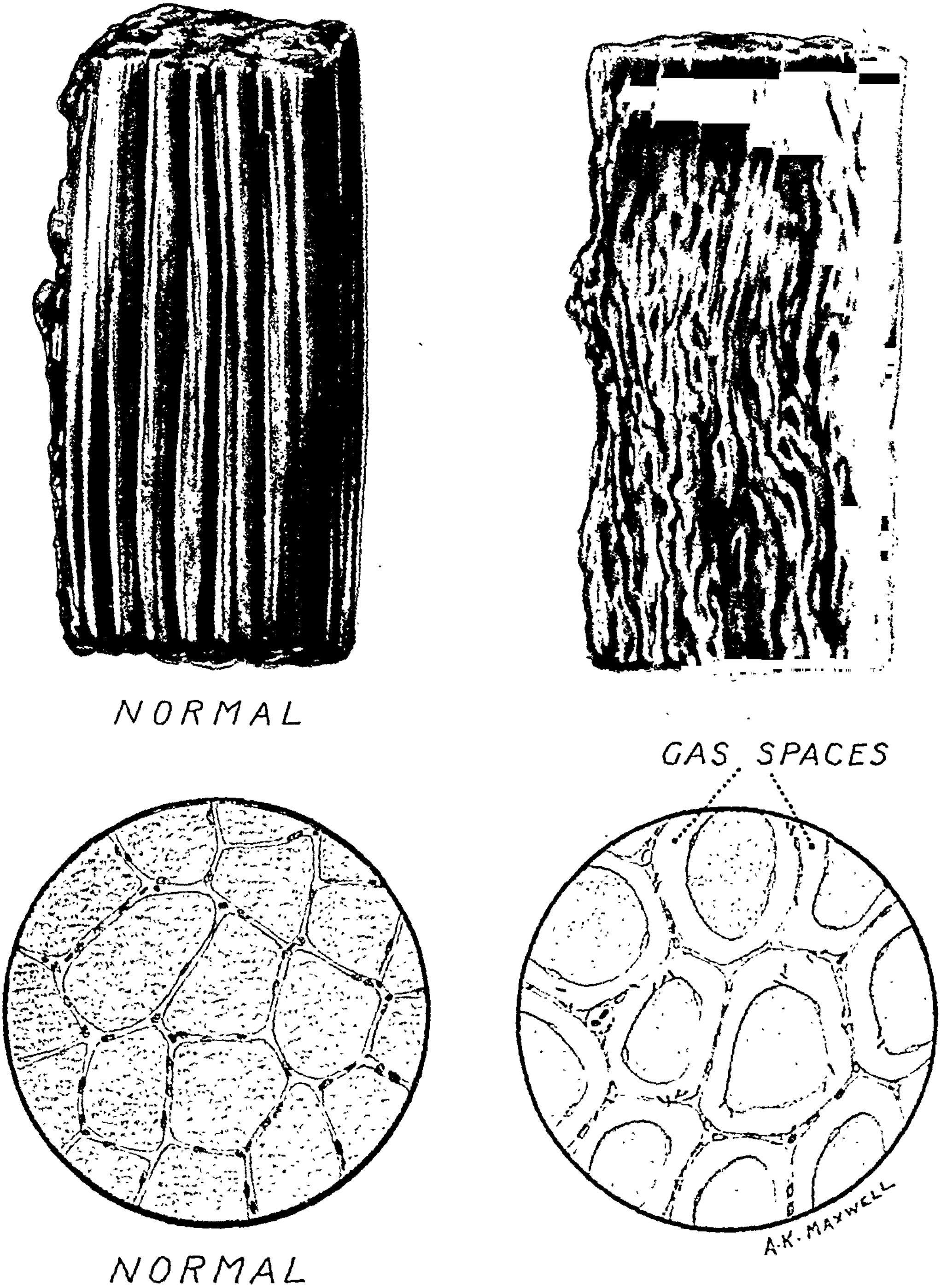
Most cases usually consist of mixed infections; the anaërobic organisms have been found along with those of the pyogenic variety. The more important anaërobic organisms are the following:

Bacillus welchii (B. aërogenes encapsulatus, B. perfringens).
Bacillus œdematis maligni (Vibrion septique).
Bacillus œdematiens.

To these may be added a fourth, Bacillus sporogenes, which, although neither causal nor gas-producing, is responsible for much of the odour which is so characteristic of the disease. The most important of these organisms is the Bacillus welchii, a non-motile bacillus, which sometimes forms spores. It attacks carbohydrates more actively than proteins, and therefore acts especially upon the muscles, in which the infection tends to spread rapidly with abundant gas formation. Occasionally the bacilli may be carried in the circulation to a distance and produce metastatic gas gangrene; but as a rule they do not enter the blood-stream until just before death. On post-mortem examination an abundance of gas may be found in the tissues, *e.g.* the liver, brain, etc., which may show innumerable small, apparently 'empty,' sponge-like, gas-filled cavities in their substance, occasionally produced before death, but most commonly a phenomenon of decomposition occurring at or after death. B. œdematis maligni (the Vibrion septique of Pasteur) is a similar organism, but actively motile and strictly anaërobic, producing an abundance of gas from glucose. Its inoculation into mice and guinea-pigs is followed by their death within twenty-four hours, preceded by a spreading œdematous condition of the connective-tissue spaces containing multitudes of the bacilli and perhaps gas. The gas which is formed early consists of hydrogen and carbon monoxide and is odourless; but it later becomes mixed with sulphuretted hydrogen and becomes highly offensive as a result.

Symptoms.—The active outbreak of this disease may be delayed for two or three days after the occurrence of the wound, during which time the latter is perhaps a little painful but shows no special signs of activity, the absence of discharge being an unfavourable sign. In some cases the period of incubation may be as short as twelve hours. The wound, when opened, is found to be unhealthy, the surface covered with sloughs, and a thin serous or slightly sero-purulent blood-stained discharge escaping, in which the organisms may be present in enormous numbers. There is usually comparatively little or no local leucocytic reaction, unless there is mixed infection with pyogenic organisms; and the inflammatory process rapidly spreads along the connective-tissue planes, and especially in the substance of the muscles (Plate III.), *e.g.* of a limb, which becomes swollen, painful, and brawny. In one case under observation the gangrene spread from the foot to the groin within twelve hours. At first the parts show a bright red blush, but they soon become purple, gangrenous, and

PLATE II



Gas Gangrene of Muscle

The normal macroscopic and microscopic appearances are compared with those affected with gas gangrene.

crepitant. If gas in the deeper tissues is suspected, its presence or otherwise may sometimes be demonstrated by X-ray examination. The emphysema spreads widely and rapidly, with at first no other local signs; sloughing will, however, follow if the patient live long enough. Evidences of profound toxic disturbance, such as hyperpyrexia and delirium, soon manifest themselves; but not uncommonly fever may be entirely absent, the temperature being subnormal and coma present. The presence of a marked pallor and restlessness suggests the possibility of a profuse hæmorrhage, but is due to the severe toxin. The outlook is exceedingly grave, death usually ensuing in two or three days, but the clinical course may be modified by the type of gangrene present. Clinically it is possible to recognize three main varieties:

(i.) The localized variety, which is limited more or less to the area of the wound. This type is the most favourable, and cure may follow prompt and energetic treatment.

(ii.) The diffuse variety, in which the organisms spread among the muscles of the affected area, giving rise to much gaseous distension. It is the most common type, and in civil practice occurs most frequently in connection with accidents involving a severe crush of a limb.

(iii.) The fulminating variety, in which the gaseous organisms spread with great rapidity through the muscles and fascial planes to involve the greater portion of the body. The prognosis in this variety is practically hopeless, treatment being of little or no avail.

Treatment.—It is impossible to emphasize too strongly the danger of closing up completely and without drainage lacerated and contused wounds which have been caused on the battlefield, or by accidents on the railways, the street or elsewhere, whereby the damaged tissues have been brought into contact with the ground, and perhaps infected thereby with the dangerous anaërobic organisms which are so constantly present in the soil. Prophylactic injections of anti-tetanus and anti-gas-gangrene sera should be given in all cases immediately such infections are suspected, and in this connection it may also be noted that a prophylactic inoculation of anti-gas-gangrene serum may now be regarded as a routine precautionary measure against the toxins of *B. welchii* in operations upon suppurative or gangrenous conditions of the bowel wall, *e.g.* in strangulation of a volvulus or hernia, infarction, appendicitis, etc., this organism being practically a normal inhabitant of the intestine, in which, under these abnormal conditions, it may proliferate and attack the damaged or dead tissues. Absence of hydrochloric acid in the gastric juice, *e.g.* in pernicious anæmia, has also been found to favour the proliferation of *B. welchii* and other organisms of putrefaction, as well as pathogenic streptococci, etc. Scrupulous antiseptic cleansing of the wound, accompanied by the removal of dead and damaged tissues, followed by the application of bipp, loose suturing of the parts, and free drainage, are essential if dangerous consequences are to be avoided. The appearance of inflammatory phenomena will necessitate free opening of the wound, followed by incisions through infected tissues and immersion of the limb in a warm bath containing eusol or weak iodine solution.

If, in spite of this, the disease spreads, a guillotine amputation, *i.e.* without flaps, well above the visible extent of the disease, or a high ordinary flap amputation, even through the shoulder or hip-joint, is the only hope of saving life.

1. **Wound Phagedena and Hospital Gangrene** were common in the pre-antiseptic era, but are now practically unknown. They were forms of rapidly spreading ulceration or gangrene, which attacked operation wounds a few days after their infliction, and as a rule resulted in rapid death. Since the disappearance of this malady the term has been retained in connection with a certain type of sloughing ulceration of the penis, which is occasionally seen as a complication of venereal disease. This latter variety will be described in connection with the section on syphilis.

2. **Cancrum Oris and Noma.—Cancrum oris** is an infective gangrenous stomatitis—now fortunately rare in this country—affecting especially young children living in squalid surroundings in over-populated districts of large cities. The patients are always in a low state of health, perhaps convalescing from one of the exanthemata, particularly measles. The process starts in an abrasion of the mucous membrane, which, being infected, perhaps from a diseased or dirty tooth, becomes inflamed and gangrenous. A foul ashy-grey pultaceous slough forms on the inside of one of the cheeks, and from this a most offensive discharge is poured into the mouth and swallowed, the breath in consequence becoming intensely fœtid. The gangrene gradually spreads both superficially and deeply; the cheek becomes swollen, shiny, and tense, and, should the process extend through its whole substance, a black slough appears on its outer aspect (Fig. 41). In bad cases the adjacent bones of the face may be affected and become necrosed, and the tongue, palate, and even the fauces, may also be involved (Fig. 42).

The general phenomena are those of a severe toxæmia, since not only are the toxic products swallowed, but they are also absorbed by the lymphatics, and may be inhaled, in the latter case giving rise to septic broncho-pneumonia. Moreover, the patient runs a considerable risk of developing pyæmia, from implication of the facial or other veins in the necrotic process, whilst septicæmia may also supervene. Rigors and high fever may occur early in the case, but death is usually preceded by symptoms of collapse and coma, with a subnormal temperature.

The **bacteriology** of this affection is still doubtful. Enormous numbers of mixed organisms are present, but of these probably the most important is the *Streptococcus pyogenes*, perhaps in conjunction with a fusi-spirochætal (Vincent's) or other infection.

The **Treatment** must be prompt and energetic if the child's life is to be saved. The patient should be anæsthetized, and all the pultaceous slough removed by cutting or scraping, until healthy bleeding tissue is reached. The denuded surface is then freely rubbed over with pure carbolic or strong nitric acid. In using such agents, the throat must be carefully protected, and the excess of acid in the case of the former dissolved by spirit, and in the latter neutralized by

Fig. 41.—Cancrum Oris. A Fatal Case in an Infant. The Extensive Ulceration can be seen.

Fig. 42.—Cancrum Oris in a Child, showing Necrosis of the Lower Jaw.

bicarbonate of soda. If the bones of the face are involved they must be removed, as also any offending teeth. Afterwards the mouth is to be washed out frequently with antiseptic lotions, such as a solution of peroxide of hydrogen (1 in 10), boro-glycerine (1 in 20), or permanganate of potash. The child must be given plenty of suitable fluid nourishment, and, if need be, stimulants. In the most severe cases, the whole thickness of the cheek may be attacked; loss of substance must be made good by subsequent plastic work. Necessarily, the cicatrization following this destructive process results in considerable permanent impairment of the movements of the jaw.

Noma is the name given to a similar process occurring about the genital organs of children, especially the vulva. The **Treatment** is practically the same, except that here it is possible to immerse the patient in a warm antiseptic bath of potassium permanganate, after having removed the infected tissues.

CHAPTER VI.

SPECIFIC INFECTIVE DISEASES.

Erysipelas.

ERYSIPELAS is a contagious infective disease almost always, in the human subject, due to the development of one of the various strains of the hæmolytic *Streptococcus pyogenes* in the smaller lymphatics of the skin and occasionally of mucous membranes, with a decided tendency to spread, and to recovery without loss of tissue, the constitutional symptoms being due to the absorption of toxins developed locally. Occasionally the subcutaneous connective tissue is also involved, constituting the variety known as **cellulo-cutaneous erysipelas.**

The organisms gain entrance into the body through an abrasion or wound, particularly if dirty. As abrasions are common on unprotected areas such as the face, hands, and arms, it follows that erysipelas is seen most frequently in those sites. Its development is facilitated by a weak or depressed state of health, and hence it is a very severe and often fatal disease in infants and old people. Bad hygienic surroundings and overcrowding are important predisposing factors.

The **Symptoms** of the disease usually commence with headache and malaise, followed, in about twenty-four hours, by a slight rigor, well-marked pyrexia, and the development of the rash, spreading either from the margin of the wound, or showing itself in apparently unbroken skin as in the so-called 'idiopathic' variety. If there is a wound, it usually presents a yellowish, unhealthy-looking surface, with very little evidence of repair. When the infection is an unmixed one, the healing process may continue until the rash appears on the third or fourth day, when the wound breaks open again, exposing a dry and sluggish surface with a thickened margin. The erythema is generally of a characteristic vivid rosy-red colour disappearing on pressure, and accompanied by a sensation of stiffness or burning, scarcely amounting to pain, except when dense structures, such as the scalp, are involved, and then the pain may be severe. Swelling is not marked, except in loose areolar structures, such as in the eyelids or scrotum; the œdema may then attain considerable proportions. In a typical case the erythema continues to advance more or less rapidly, with an abrupt continuous slightly raised margin, and as it spreads to new regions it fades away from those already involved, leaving a slight brownish pigmentation and a fine branny desquamation. In some cases it does not spread regularly, but appears to leap over an interval, the infection having travelled by the intervening lymphatics, which are found to be thickened. Vesicles and bullæ may form, containing

serum, which speedily becomes turbid; but suppuration is uncommon, except in lax œdematous tissues, *e.g.* the eyelids. Occasionally, from the severity of the inflammation or the low state of vitality of the tissues, the skin may become gangrenous and slough, especially about the umbilicus and genitals of young children. Neighbouring lymph-nodes are enlarged and painful, and this may be noted even before the rash has appeared. Periphlebitis may also be caused, and may lead to thrombosis and perhaps pyæmic complications. Fever is present as long as the rash persists, and shows merely slight diurnal variations. It is not uncommon for the temperature to reach 104° F., but any rise above this is of grave significance. At first the fever is of a sthenic type, the pulse full, and delirium, if occurring, noisy and active; but later the pulse becomes quick and weak, accompanied by low, muttering delirium and great prostration. A polymorphonuclear leucocytosis, moderate in degree (12,000, 15,000 or perhaps 20,000 per cubic millimetre), is usually present in the blood. The duration of the attack is very variable, lasting, as a rule, from one to three weeks, but relapses are not uncommon. The swelling of the part does not always clear up entirely, owing to persistent blocking of lymphatics; when repeated attacks occur, this swelling may become so great as even to simulate elephantiasis.

Celullo-cutaneous Erysipelas, as already stated, is a clinical variety in which there is marked infection of the subcutaneous tissues, resulting in a diffuse infiltration and œdema of these tissues, and less often in suppuration or even sloughing of the skin and subjacent cellular tissue. The infiltration is at first brawny in type but subsequently softens and becomes boggy, the skin finally giving way to allow an exit for pus and sloughs. The general symptoms are correspondingly severe, and pyæmia may supervene. As features distinguishing it from ordinary erysipelas it may be mentioned that the margin of the redness is less defined and that the lymph-nodes are less enlarged.

Erysipelas of the scrotum, sometimes seen in infants following a circumcision, is characterized by the part becoming greatly distended with serum, but without any marked redness. Suppuration and sloughing are not unlikely to follow. It may thus sometimes simulate the appearance produced by extravasation of urine, but is distinguished from it by the facts that micturition is usually not interfered with and that the swelling is not limited in the same way as in the latter affection.

Pathological Anatomy.—On microscopical section of the affected skin, very numerous cocci arranged in chains will be found invading the lymphatics just beyond the spreading margin, whilst in the inflamed area there is a considerable excess of leucocytes, blocking the lymphatics, and evidently engaged in the destruction and removal of the cocci, since phagocytic inclusion of the organisms is frequently observable. The lymph-nodes will also be found enlarged and congested. Fatal cases otherwise show merely the ordinary post-mortem signs of death from a general toxæmia or septicæmia.

Diagnosis.—The points to be noted are the bright red colour of the rash, the irregular, sharply defined and raised edge and the frequent

accompaniment of tiny areas of vesication. It has to be distinguished from the exanthemata and other varieties of erythema, *e.g.* sunburn, ultra-violet radiation, or dermatitis venenata.

Prognosis depends upon the presence or absence of complication. The disease in itself is not of a serious nature, although the toxæmia may be very great in debilitated people. The complications are all serious, the common ones being pneumonia, meningitis, and pericarditis.

Treatment.—Erysipelas is a notifiable disease under the Infectious Diseases Acts, and the patient must be isolated and, if possible, removed from a surgical or obstetric ward. If this is impracticable, the patient must be placed as far away from others as possible, especially from surgical cases, and it is wise, under these circumstances, to put off all operations that can be safely postponed.

General Treatment.—This should be of a tonic and supporting character. The food should be good and easy of assimilation and stimulants should be given as required. Of internal remedies tinct. ferri perchlor. (dose, ♏. xx-xxx) is the most effective and sometimes acts as a specific. Collosol manganese (½-2 c.c. daily for three to four days), quinine (gs. iii-v, t.d.s.), and S.U.P. (1 c.c. daily) are less effective remedies but may be tried. The introduction of drugs of the *sulphonamide* group has, however, been of the first importance in this disease, and undoubtedly they form specific remedies. They should be given in full dosage. Antistreptococcal serum in dosage up to 50 c.c. daily may also be employed, but is probably of less value than the sulphonamide preparations.

Local Treatment.—The most effective local preparation is undoubtedly a saturated solution of magnesium sulphate, applied in the form of a cold pack, from which crystals of salt separate out on the skin. It is especially useful where there is much pain. Alternatively a 20 per cent. solution of subitol may be applied, or lotio plumbi containing opium (laudanum, 1 ounce to the pint). Ichthyol, in the form of an aqueous solution (20 to 40 per cent.) or ointment (10 per cent.), is also a very satisfactory remedy and should be applied continuously.

In cellulo-cutaneous erysipelas early and free incisions must be made to relieve tension, and, if possible, anticipate suppuration. The tissues, when incised, look gelatinous from the œdema present, and much fluid of a sero-purulent type will escape. Antiseptic fomentations or hypertonic applications should be employed after the incisions have been made, until granulations have developed.

Diphtheria.

Diphtheria is an infectious disease due to the Bacillus diphtheriæ (the Klebs-Löffler bacillus), which is a non-motile, Gram-positive organism about 3 or 4 μ in length (Plate I., Fig. 7), staining irregularly, particularly at the poles, and thus presenting a beaded appearance. The infection may be transmitted directly by the discharges, or indirectly as in milk. The bacilli may occasionally be found in a virulent condition in the throats and nasal fossæ of apparently healthy

individuals, who act as 'carriers,' and may thus lead to outbreaks of the disease without obvious cause. The disease usually involves the mucous membranes, particularly those of the pharynx, larynx, and nasal passages; occasionally it attacks open wounds, the skin, conjunctiva, or the genitals. It is characterized by the formation locally of a fibrinous exudate, closely incorporated with degenerating or necrotic superficial layers of the tissues affected—the so-called diphtheritic 'false membrane'—so that attempts to remove it cause slight bleeding. Constitutional symptoms are due to the absorption of bacterial exo-toxin. The bacilli themselves remain limited to the local lesion, which may be found anywhere in the nose and throat, but which does not give rise to serious disturbance except when the membrane develops in the larynx (membranous croup), in which case grave laryngeal obstruction may occur; when this event takes place, tracheotomy or intubation should be performed at once. The general effects produced by the absorption of the toxins are seen mostly in connection with paralysis of the palatal and orbital muscles, and less frequently the diaphragm and muscles of the limbs. Cardiac weakness is also not uncommon, and is due partly to degeneration of muscle and partly to action on the vagus. The toxin has considerable poisonous effect on the kidneys and albuminuria is common.

The characteristics of pharyngeal and laryngeal diphtheria are described under their respective headings.

Treatment.—The most important point is the immediate administration of antitoxic serum in doses of from 8,000 to 120,000 units* given intramuscularly or intravenously, depending upon the severity and urgency of the case—the latter route being chosen in the more urgent cases, and the dose repeated if no improvement within twelve or twenty-four hours ensues. Children require as large doses as adults, or even larger. The subcutaneous route may be used to supplement either of the other two, or when the serum is given as a prophylactic measure. The value of the treatment depends largely on the promptitude with which it is applied, the mortality from diphtheria being practically nil among patients who receive antitoxin on the first day of the disease, and rising steadily with delay. In all cases where there is a reasonable probability that the infection is diphtheritic, serum should, therefore, be administered immediately, and without awaiting the result of the cultural bacteriological examination. In addition, local antiseptics are useful, and in laryngeal cases, where dyspnœa occurs from obstruction of the larynx by membrane, tracheotomy or intubation may be necessary. Suitable prophylactic immunization, passive with the antitoxic serum, active with concentrated toxoid (Formol-Toxoid, F.T.), or mixtures of toxoid and antitoxin (Toxoid-Antitoxin Mixture, T.A.M.), may be employed to protect those found to be 'Schick-positive.'

* The unit is the amount of antitoxin which will neutralize 100 times the minimum lethal dose of toxin required to kill a guinea-pig of 250 grammes in four days.

PLATE III

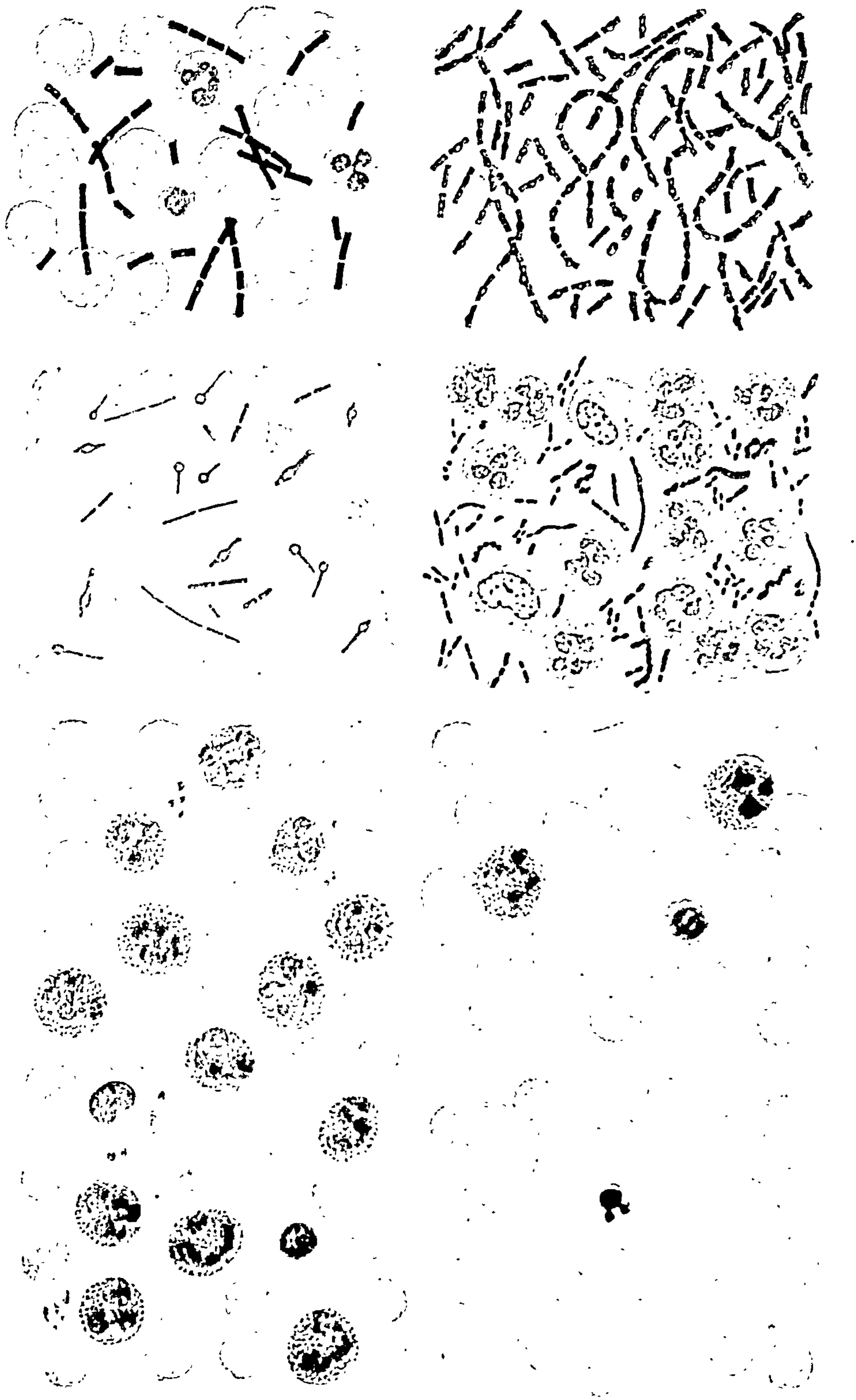


PLATE III.

Fig. 1.—Film from Blood of Guinea-pig infected with Anthrax.

The bacilli are Gram-positive and do not form spores in the living body. (Gram's Stain, ×1000.)

Fig. 2.—Film of Anthrax Bacilli from Three-days' Agar Culture, showing Central Spore-formation within the Bacilli.

A few fully-formed oval spores are present. (Rd. Muir's Stain for Spores [Carbol-Fuchsin and Methylene Blue], ×1000.)

Fig. 3.—Film of Tetanus Bacilli from Wound.

The typical rounded terminal 'drum-stick' spores are seen on some, but have not yet developed on others, of the slender bacilli. Thicker (unidentified) bacilli, some with sub-terminal oval spores, are also present. (Weak Fuchsin, ×1000.)

Fig. 4.—Film showing *Bacterium coli* and Streptococci in Centrifugalized Deposit from Case of Purulent Cystitis.

The Gram-negative *Bacterium coli* is very variable in size. (Gram's Stain, ×1000.)

Fig. 5.—Blood-film showing Marked Polymorphonuclear Leucocytosis from a Case of Acute Suppuration.

The red corpuscles have to some extent taken on the blue stain. Two small lymphocytes and several groups of blood-platelets are also shown in the field. No eosinophils are present. (The drawing has been made towards the end of the film, where the leucocytes were more crowded than elsewhere.) (Leishman's Stain, ×1000.)

Fig. 6.—Normal Blood-film for Comparison with Figs. 4 and 6.

Two polymorphs and a small lymphocyte are shown along with the normal red corpuscles. (Methylene Blue and Eosin, ×1000.)

Fig. 7.—Blood-film from a Case of Marked Secondary Anæmia in Malignant Disease.

The red corpuscles show irregularity in size and shape, and diminution in hæmoglobin. A normoblast with fragmenting nucleus is shown. (Jenner's Stain, ×1000.)

... of pyogenic organisms, ... present, co-operate in ... i. Hence it is rare for the ... been maintained and rapid repair effected, and it is very uncommon, though possible, for it ... after blows or bruises with no visible breach of surface. Wounds due to blank cartridges, since the injury is largely due to ... which may be made of coarse horsehair ..., and is therefore ... contain spores of the bacillus, are often followed by tetanus,

PLATE III.

FIG. 1.—FILM FROM BLOOD OF GUINEA-PIG INFECTED WITH ANTHRAX.

The bacilli are Gram-positive and do not form spores in the living body. (Gram's Stain, ×1000.)

FIG. 2.—FILM OF ANTHRAX BACILLI FROM THREE-DAYS' AGAR CULTURE, SHOWING CENTRAL SPORE-FORMATION WITHIN THE BACILLI.

A few fully-formed oval spores are present. (Rd. Muir's Stain for Spores [Carbol-Fuchsin and Methylene Blue], ×1000.)

FIG. 3.—FILM OF TETANUS BACILLI FROM WOUND.

The typical rounded terminal 'drumstick' spores are seen on some, but have not yet developed on others, of the slender bacilli. Thicker (unidentified) bacilli, some with subterminal oval spores, are also present. (Weak Fuchsin, ×1000.)

FIG. 4.—FILM SHOWING *Bacterium coli* AND STREPTOCOCCI IN CENTRIFUGALIZED DEPOSIT FROM CASE OF PURULENT CYSTITIS.

The Gram-negative *Bacterium coli* is very variable in size. (Gram's Stain, ×1000.)

FIG. 5.—BLOOD-FILM SHOWING MARKED POLYMORPHONUCLEAR LEUCOCYTOSIS FROM A CASE OF ACUTE SUPPURATION.

The red corpuscles have to some extent taken on the blue stain. Two small lymphocytes and several groups of blood-platelets are also shown in the field. No eosinophils are present. (The drawing has been made towards the end of the film, where the leucocytes were more crowded than elsewhere.) (Leishman's Stain, ×1000.)

FIG. 6.—NORMAL BLOOD-FILM FOR COMPARISON WITH FIGS. 4 AND 6.

Two polymorphs and a small lymphocyte are shown along with the normal red corpuscles. (Methylene Blue and Eosin, ×1000.)

FIG. 7.—BLOOD-FILM FROM A CASE OF MARKED SECONDARY ANÆMIA IN MALIGNANT DISEASE.

The red corpuscles show irregularity in size and shape, and diminution in hæmoglobin. A normoblast with fragmenting nucleus is shown. (Jenner's Stain, ×1000.)

Tetanus.

Tetanus is a local infective disease, due to Bacillus tetani, associated with a characteristic toxæmia. The bacillus occurs in the form of delicate straight rods, which sometimes grow into threads. It is a strict anaërobe, and usually develops a characteristic spherical terminal spore, giving it the appearance of a drumstick (Plate III., Fig. 3). Such spores appear both in the pus of the wound and in cultures, and are extremely resistant to the action of heat (they usually survive boiling for at least five minutes) and antiseptics. The bacilli stain by Gram's method and possess numerous flagella. They of themselves do not tend to proliferate actively in the tissues unless the vitality of these is also lowered by the action of the toxin itself, or by the products of other bacteria, or the presence of a foreign body such as a splinter of wood, earth, etc., or by other damage to the tissues, *e.g.* the fracture of bone. When washed completely free from their toxins the spores often fail to produce tetanic symptoms, when injected even into susceptible animals; should, however, a minute trace of toxin be present, it so depresses the vitality of the surrounding tissues that the spores develop into bacilli, which then continue to proliferate and produce more toxin.

Ætiology.—The causal organism is a facultative saprophyte, and is almost constantly found in garden soil, and street, stable, farm, and road refuse. Those, therefore, who are brought in contact with the ground, *e.g.* gardeners and agricultural labourers, are specially liable to the disease, particularly if the soil has been persistently and heavily manured. Horses also are very susceptible to tetanus, and the bacilli are usually present in their fæces; hence stablemen and others engaged in looking after horses are attacked with comparative frequency. The disease is more often seen in the tropics than in other climates, probably owing to the heat favouring the development and virulence of the organisms in the soil.

The existence of a **wound** can almost always be demonstrated, usually of a dirty, lacerated or punctured character, and suppuration is generally present. Any part of the body may be thus affected, but perhaps those regions, such as the sole of the foot or the palm of the hand, which are liable to be brought into contact with contaminated soil are most often involved. Street and road accidents and war-wounds are only too likely to be followed by tetanus. The depressed vitality of the tissues owing to the bruising and tearing, the irritation caused by the growth of pyogenic organisms, and the absorption by the latter of any oxygen present, co-operate in favouring the development of the tetanus bacilli. Hence it is rare for the disease to affect wounds where asepsis has been maintained and rapid repair has been effected, and it is very uncommon, though possible, for it to develop after blows or bruises with no visible breach of surface. Gunshot wounds due to blank cartridges, since the injury is largely due to the wad, which may be made of coarse horsehair felt, and is therefore likely to contain spores of the bacillus, are often followed by tetanus,

as are also 'Fourth of July wounds' in the United States due to firework burns. Commercial gelatin derived from the hoofs, etc., of horses often contains the bacilli, and the injection in the treatment of aneurisms of this substance, when imperfectly sterilized, has been followed by the disease; and similarly the use of surgical catgut infected with spores which have escaped sterilization may cause tetanus. Occasionally the bacilli gain entrance into the tissues through trivial, *e.g.* small punctured, wounds which may heal over superficially, or in connection with lesions such as frost-bite, and they may even persist for a while in a latent condition, developing only after an interval of some weeks or months. This is the explanation of those cases of tetanus which used to be termed 'idiopathic,' *i.e.* where no obvious cause in the shape of a wound could be detected, and it also explains the incidence of tetanus after operations upon areas previously the site of infected wounds. Tetanus neonatorum, due to infection of the cut end of the umbilical cord, was common in pre-antiseptic days.

Pathology.—Tetanus is, perhaps, the most characteristic example of a local infection causing a general toxæmia. The bacilli remain in or near the wound, and do not enter the blood or reach distant parts of the body. The toxins produced locally act on the central nervous system in a manner very similar to strychnine, thereby increasing reflex excitability of the motor mechanism, so that slight stimuli produce excessive muscular contractions of a tonic character.

The method of transit from a local wound to the central motor nerve-cells is peculiar in that the toxin is not absorbed by these cells from the blood or lymph, from which fluids it quickly disappears, but is picked up locally, or from the blood or lymph, by the end-plates of the nerves in the muscles, and thence is carried up along the motor nerves, either by the lymphatics of the nerves or by the protoplasm of the axones themselves. Naturally when an infected wound involves muscles, the transference of toxin along the motor nerves of this region is facilitated, and the cells of the spinal cord controlling this area may be affected earlier than others, and so a localized form of tetanus results. It has been experimentally found possible to protect certain areas by injecting antitoxin into the motor nerves; thus if a full intravenous dose of toxin is given to an animal, and shortly afterwards antitoxin is injected into both sciatic nerves, tetanus develops in the usual manner in the head, trunk, and fore-limbs, but the hind-legs are not affected. Clinically, if no localizing lesion thus leads to the selection of special areas, the muscles of the jaw and neck appear to have a specific predilection for the toxin, and it is probable that the toxin reaches the motor nerve-cells through the nerves leading from these muscles.

The post-mortem anatomical changes are not characteristic. The muscles are often pale, or show evidences of rupture or extravasation of blood. The peripheral nerves extending from the wound may be red and congested for some distance; this may not be due to the action of the toxin (which appears to produce no demonstrable lesions of the nerves themselves), but to coincident pyogenic inflammation. The

nerve-centres frequently present areas of softening and perivascular cellular exudation, with some hyperæmia, especially in the pons and medulla. Degenerative changes may also be evident in the anterior cornual nerve-cells of the cord.

Clinical History.—The **incubation period** varies from twenty-four hours to three weeks, and is also considerably influenced by the prophylactic administration of antitetanic serum. As a general rule, in temperate climates the average incubation period of acute cases is from one to two weeks, but in the tropics the disease may appear after a few hours (**Tetanus Fulminans**).

During the period of incubation there may be some local tenderness or swelling of the wound and some rigidity or twitchings of the muscles may develop locally. The disease is usually ushered in by the appearance of **Trismus,** hence the popular name of **Lockjaw** for the disease.

The patient complains of a difficulty in opening the mouth, associated with a cramp-like pain in the muscles of mastication and of the neck. This soon becomes so marked that even a paper-knife cannot be inserted between the teeth, causing great difficulty in the administration of food; to it is added a fixed and rigid condition of the muscles of the back of the neck and of the face, the latter producing a curious grin-like appearance (**risus sardonicus**), whilst dysphagia is sometimes caused by spasm of the pharyngeal muscles. A considerable degree of fever is often present, but in some cases an apyrexial course is maintained until nearly the end. The spasms soon become generalized and extend to the trunk and extremities, accompanied by cramp-like pains, and when fully established they may be excessively painful and violent, and the remissions between them but partial. The disease usually involves the respiratory muscles late in the attack. The more severe spasms can be excited by any form of stimulus, such as a bright light, the slamming of a door, a draught of cold air, or some voluntary movement, and are always of a tonic, *i.e.* continuous, character. The body is contorted in various directions, and respiration may be much impeded by the fixation of the thorax. Occasionally the body is arched backwards (**opisthotonos**) by the contraction of the muscles of the back, the recti abdominis being firm and tense—'as hard as boards'; sometimes it is doubled forwards (**emprosthotonos**), and in rare cases laterally (**pleurosthotonos**). The muscles may contract so violently as to be ruptured, whilst bones have been fractured, teeth have been broken, and the tongue has been almost bitten off. The intellectual faculties usually remain clear to the end, which is generally brought about by exhaustion from repetition of the convulsions, or more rarely by asphyxia induced by a prolonged fixation of the respiratory muscles. Before death the temperature sometimes may rise to 108°, or even, as in one case recorded, to 112° F., and it often continues to rise for a degree or two after death; such hyperpyrexia is due mainly to the continuous muscular contractions. The surface of the body is bathed in sweat, and the urine is scanty, and occasionally albuminous. Death may occur in twenty-four hours from the onset of the disease, or perhaps not for four or five days.

Another uncommon clinical variety is **Head Tetanus** (Cephalo-tetanus), which sometimes occurs after head injuries. It is due to local nuclear involvement following absorption and diffusion of the toxins via the facial or trigeminal nerves, and leads to involvement of the motor nuclei of the third, fifth, sixth, and seventh nerves, but in rare cases the bulbar muscles may be affected. Oculomotor palsies are common and are associated with trismus and possibly pharyngeal spasm, causing severe dysphagia and bearing a superficial resemblance to hydrophobia.

Three other clinical varieties should be borne in mind. **Tetanus Neonatorum** occurs in new-born children from infection of the umbilical cicatrix. It is a very fatal disease, death occurring in one to two days. **Post-Puerperal** and **Post-Operative Tetanus** are sometimes seen after childbirth and operations. The possibility of their appearance should not be forgotten.

Chronic Tetanus is a clinical variety which shows a longer incubation period between the infection and the onset of the symptoms, which are less severe in degree, and the prognosis is better. The course is often afebrile, and the spasmodic contractions may be limited to the wounded part of the body where the infection has commenced. Sometimes the patient lies in bed with the jaw partially fixed, and the muscles of the neck, back, and abdomen rigidly contracted, but often with none of the characteristic convulsions.

Diagnosis.—In the early stages tetanus must be distinguished from simple 'trismus' arising from dental irritation, from gastric and other forms of tetany, and from inflammatory ankylosis of the temporo-maxillary joint. This may be readily accomplished by noting that rigidity of the neck muscles is also present in tetanus. Strychnine poisoning leads to a very similar group of symptoms, but is recognized from tetanus by the contractions being more sudden and violent, the relaxation of the muscles between the spasms complete, so that the mouth can readily be opened, whilst the hands are involved in the contractions—a rare occurrence in tetanus—and the muscles of mastication often escape.

No difficulty should be experienced in distinguishing tetanus from hydrophobia, owing to the very different nature of the convulsions in the latter, *i.e.* clonic and not tonic; moreover, they affect the muscles of respiration and deglutition, whilst the history of the case, the early hallucinations, and the absence of tonic muscular contractions, are also characteristic features.

After the appearance of the symptoms, the **Prognosis** is unfavourable in any case, but the longer the disease lasts, and the lower the temperature, the more likely is the patient to recover, whilst an acute onset, hyperpyrexia, sleeplessness, delirium, and strabismus are bad signs. The length of the incubation period is also a most important factor. Generally speaking, cases developing under five days are fatal; in those developing in from five to ten days 90 per cent. are fatal; from ten to twenty days the mortality is 75 per cent.; while cases developed after three weeks usually recover.

Treatment.—In localities where tetanus is known to be rife, it is ad-

visable always to administer a **prophylactic** dose of antitetanic serum in cases of wounds or abrasions that might possibly be infected, especially if due to street accidents, etc. (see above, under Ætiology), or if suspicious bacilli are found on microscopical examination of a scraping from the deeper parts of the wound. For routine prophylactic injection, the minimum dose should be 1,000 International (=500 U.S.A.) units,* repeated several times at seven-day intervals; but, and especially if there is much contamination of the wound, or much delay has occurred, it is preferable to give 3,000 International (=1,500 U.S.A.) units, or even more. In cases where it is proposed to attempt to clean out or excise the wound surgically, the serum should be injected intramuscularly some three or four hours previously.

The moment any actual symptoms of the disease have appeared, **no delay** in administering antitoxin in full doses should be permitted, and in this connection it is again wise to insist that the disease can often be recognized before trismus has occurred. The modern tendency is to administer antitoxin in much larger doses than were previously considered adequate. Treatment should commence immediately with an intrathecal injection, preferably into the cisterna magna (the cerebello-medullary cistern) rather than by the lumbar puncture route, of 40,000 International (=20,000 U.S.A.) units or more, and for this the most concentrated and potent antitoxin available should always be employed. The amount of cerebro-spinal fluid withdrawn should be a little less than the bulk of the proposed dose, and the patient's head is lowered after the administration. At the same time intravenous and intramuscular injections of, say, at least 20,000 International (=10,000 U.S.A.) units each should also be given. Should there be no improvement by twelve to eighteen hours, these doses should be repeated, and again every twenty-four hours for three or four days. Then, if necessary, 30,000, 25,000, or 20,000 International (=15,000, 12,500, or 10,000 U.S.A.) units may be given daily intramuscularly, if possible in the immediate neighbourhood of the motor nerves of the affected part. Until all danger of relapse appears past, smaller doses may be administered subcutaneously every few days.

The **treatment of the wound** is of great importance, for, of course, the antitoxin treatment deals only with the toxic bodies absorbed from it, and has no influence upon the local infective processes. Much will depend upon the position and extent of the wound or wounds, and, where these are multiple, upon whether the infection with the tetanus bacilli has occurred in one only or in several. The surgeon must consider whether thorough excision of the wound is feasible; or whether, when the infection has occurred in a limb, amputation well above its site, as removing completely the source of the toxin, is inevitable; or whether he may safely rely upon the local application of oxidizing antiseptics and satisfactory drainage. It is certain that any injudicious manipulation of the wound may do more harm than good by distributing toxin, and therefore one's choice must be between

* The Ministry of Health has adopted a unit which is one-half the strength of the well-known U.S.A. unit. Both standards are, therefore, usually stated on the label of most commercial antitetanus sera.

an amputation well above and conservative measures. The former has certainly proved very successful in suitable cases, and when the causal wound is deep, involving muscles and bones, badly infected and difficult to sterilize, amputation is often the method of choice. In the less serious cases after a suitably large preliminary dose of serum the wound should be opened up thoroughly and yet with the greatest possible gentleness, any foreign body searched for and removed, and the wound cleansed with oxidizing antiseptics, and dressed with hypertonic salt solution or treated by Carrel's method. The appearance of healthy granulations will probably synchronize with an amelioration of the symptoms.

As to **symptomatic treatment,** the chief essential is to keep the patient quiet in a darkened room and free from all sources of irritation which would produce reflex spasm of muscles. Sodium amytal, avertin (tri-brom-ethyl alcohol), hyoscyamus, chloral hydrate, bromide of potassium, chloretone, and other sedatives—morphine and atropine in specially severe cases—are of value in reducing reflex excitability and calming the nervous system, and must be given in full doses. Food should be nutritious, fluid, and unstimulating; it has been suggested that the patient should be fed twice a day by stomach-tube under an anæsthetic, or by a soft rubber catheter through the nose, but rectal feeding may in suitable cases be tolerated, and, indeed, the patient must be given an abundance of normal saline and of glucose solution by this route or, if necessary, by intravenous and subcutaneous injection.

The spasms can be diminished or almost abolished by the intrathecal or subcutaneous injection of a sterilized solution of sulphate of magnesia, which paralyzes the motor cells; 2 to 4 c.c. of a 25 per cent. solution may be given by lumbar puncture, or 10 to 20 c.c. of a 10 per cent. subcutaneously every four hours. Inhalations of chloroform are also of great value in controlling the number and intensity of the spasms.

Hydrophobia or Rabies.

Hydrophobia or rabies is an acute general infective disease, transmitted from animals, especially rabid dogs, wolves, and cats, to other animals or to man. It consists in an affection of the central nervous system, and one of its most marked features is the long and variable incubation period. It never originates 'idiopathically' either in animals or man, infection usually following a bite; but experimentally it can be transmitted through unbroken mucous membrane, *e.g.* of the nose. It has also been proved that if an affected animal merely licks an abraded surface the disease may be transmitted, even when the animal has not at the time shown any of the more typical signs of rabies.

In the **Dog,** rabies manifests itself about three to five weeks after infectfon. but the period varies considerably; the original wound usually heals perfectly, or there may be some inflammatory thickening. The dfsease first shows by a complete change of character, which is manifested possibly by snappishness and irritability, especially towards

incubation stage of the disease. The circulation in the limb should be arrested by a string or bandage, bleeding encouraged, and, if free excision of the part is not feasible, the actual cautery or some powerful caustic, *e.g.* fuming nitric or pure carbolic acid, applied. Even if such application is not made in time to prevent the occurrence of the disease, the onset of the symptoms may be thereby delayed and time gained for the prophylactic treatment by the original Pasteur method, or one of its more recent modifications. Such treatment is usually administered only at a fully equipped Pasteur Institute, to which the patient is sent without delay; but some years ago the Board of Health of New York City instituted the practice of mailing to physicians material for the Pasteur treatment, full directions accompanying each package. It has been found that the results compare quite favourably with the results of treatment given in laboratories. All American State laboratories are now able to furnish treatment in this way. Treatment with antirabic serum and more recently with various types of vaccine, *e.g.* carbolized 'fixed virus' or 'etherized' vaccine, has also been carried out, apparently with marked success, in some of the Pasteur Institutes. In cases where such prophylactic treatment has not been carried out, and in which active symptoms have appeared, only **palliative treatment** can be adopted. Every source of irritation and disturbance must be removed, and the patient kept absolutely quiet. Local applications to the pharynx are useless, and for adults the only drug of value is hyoscine combined with morphia. In children, chloral and sulphonal are of value. Nourishment should be administered for choice by the rectum.

Anthrax.

This disease results from infection with *Bacillus anthracis*, which produces in sheep, cattle, and other animals the so-called **splenic fever,** characterized by well-marked fever and enlargement of the spleen. In man, if the organism is inoculated through the skin, it produces a local inflammatory lesion, known as **malignant pustule,** or a more diffuse condition termed **anthrax œdema**; sometimes the latter follows the former. If the infecting bacilli are inhaled into the trachea and bronchi, they produce a spreading inflammatory disorder, known as **woolsorter's disease.** An intestinal form of infection also occasionally occurs.

B. anthracis (Plate IV., Figs. 1 and 2) is one of the largest of the pathogenic bacteria. It is found in the blood of diseased animals in the form of bacilli, single or in chains. It is aërobic, non-motile, grows best at about blood heat, and liquefies gelatin. Central oval spores are formed within the bacilli, *e.g.* on the contaminated hair or in the hides, etc., of such animals after death, or on articles contaminated with their blood: and also when the organism is cultivated at a suitable temperature and in the presence of oxygen; but spore-formation does not occur in the living tissues. The bacilli alone are readily killed by boiling for a few seconds, whilst the decomposition of the carcase in which they are present causes their death in about a week or less. The spores, however, are very resistant, for whilst a

1 per cent. solution of carbolic acid kills the bacilli in two minutes, the spores remain alive after a week's immersion. Moreover, alcohol and even a 5 per cent. solution of carbolic acid have no lethal effect on them, unless acting for a long time. If a mouse is inoculated, say, at the root of the tail with a needle, the point of which has been dipped in the blood of an animal which died of splenic fever, it succumbs in less than twenty-four hours, and bacilli are found in nearly every organ of the body. The spores, even when dried, may survive for many months and even years.

Some animals are immune against the attacks of anthrax, especially the dog and the white rat. One of Pasteur's most useful discoveries was that of providing artificial immunity for cattle and sheep, which are highly susceptible to the infection, by inoculating them with an 'attenuated virus,' obtained by growing the bacillus for some time at 42° C., at which temperature it is rendered asporogenous.

Incidence.—Infection with this organism occurs chiefly amongst farmers and others who tend the living animal, or butchers who deal with the carcase; and also amongst workers who handle hides, wool, or hair. The infection has in some cases been traced to the use of shaving brushes made from bristles contaminated with anthrax spores.

Malignant Pustule is seen usually on the face or forearm, or in the case of meat- or hide-porters, about the neck or shoulder. It commences as an angry red pimple at the site of inoculation, and rapidly spreads, with much infiltration of the base, whilst the centre becomes covered with vesicles, the serum within being blood-stained or dark brown in colour, and containing the typical bacilli. This stage develops by the third day but is associated with no pain, only with great itching and irritation. The pustule develops, and by the fifth day the centre has darkened into a brownish-black slough (*L. anthrax*, black), around which is a ring of vesicles with an area of brawny congestion and œdema beneath and around it. Neighbouring lymph-nodes also become enlarged. Generally, there is a certain amount of fever and malaise, which is not pronounced until about the fourth or fifth day. The temperature then rises to 102° or 103° F., the pulse becomes rapid and irregular, and gastric irritability, vomiting, and flatulence more marked. Should the disease progress unchecked, the surrounding parts are involved in a rapidly spreading œdema; thus from the face it may extend to the neck, chest, and back. The respirations become shallow and embarrassed, whilst signs of grave constitutional disturbances, such as delirium or coma, manifest themselves, and the patient may succumb, generally in less than a week, sometimes in thirty to forty hours. More commonly the case runs a less unfavourable course, limiting itself to the local manifestations, which gradually clear up, the slough separating and the œdema disappearing.

Anthrax Œdema, though usually occurring in association with malignant pustule, may occasionally develop without the formation of that type of lesion. It tends to run a rapidly fatal course, and is usually seen about the face, the skin becoming red and brawny, as in ery-

sipelas, and after a time covered with vesicles, whilst finally gangrenous patches appear. The lymphatic trunks and nodes are also involved.

The condition may be mistaken in the localized form for accidental vaccination or for a staphylococcal infection, but is recognized by the presence of the bacilli in the serum of the vesicles; in cases of doubt cultures and animal inoculations should be made.

Woolsorter's Disease is the term applied to the condition in which the infection gains access by the inhalation of the dried spores. The primary lesion is usually in the mucous membrane of the lower part of the trachea and of the larger bronchi, from which it rapidly spreads to the lung, mediastinum, and pleura. The patient complains of fever and malaise for a few days, bronchopneumonia usually develops, and the disease runs a rapid course, with high fever, great dyspnœa, impairment of the circulation, and finally collapse in a great majority of the cases. A much rarer form of the disease is the **alimentary** type, when the organisms are swallowed. In the stomach, the unspored anthrax bacilli are usually destroyed by the acid chyme; but should any of them or their spores reach the intestine, the alkaline contents form a suitable breeding-ground, and the walls of the gut are attacked and the disease becomes general. Colic, cramps, vomiting, and blood-stained diarrhœa are the most marked features in such a case. The intestinal type appears to be not quite so virulent or fatal as the pulmonary, but is decidedly worse than the cutaneous. Acute **meningitis** may follow secondarily upon any of the foregoing forms of the disease.

Treatment.—In the cutaneous affection, excision of the necrotic patch and of all the infiltrated tissues around, and the application of the actual cautery or of pure carbolic acid, were formerly recommended, but those who have had much experience think such treatment of little value, and put their trust in carbolic fomentations or mercurial ointment.

Several sera (p. 11) have been introduced for the treatment of anthrax, and good results have been obtained, especially in the localized forms of the disease. Sclavo's serum (obtained by immunizing asses or goats) has been most used, large doses being given intravenously and intramuscularly, the latter being repeated every twenty-four hours, or oftener if necessary. Sobernheim's serum, combined with vaccine treatment, has also given good results. The use of either serum may be followed by fever and sweating, and improvement is often very rapid. N.A.B. may also be used with advantage along with serum or when such serum is unobtainable.

Tularæmia.

Tularæmia is a specific infective disease of certain of the lower animals, more or less endemic in North America, Japan, Russia and Norway. It is transmitted to man especially from rabbits and certain other rodents through handling and the bites of insects. The causal organism is the Bacterium tularense, first isolated from infected ground-squirrels in Tulare County, California, by McCoy and others in 1911-12,

the name Tularæmia being bestowed upon it by Francis in 1921. The organism is a minute non-motile, Gram-negative bacillus, tending also to occur in short coccoid forms. Clinically, after an incubation period of from one to ten days, the disease is ushered in by an initial rigor and is characterized by the presence of fever, malaise and sweating. The disease tends to occur in three forms: (1) the **ulcero-glandular**, in which there is the development of an ulcer at the point of infection and the regional lymph-nodes become swollen and painful a day or two later. In (2) the **oculo-glandular** form there is a conjunctivitis and swelling of the cervical lymph-nodes and parotid glands. In (3) the '**typhoid**' type of the disease there is a more marked degree of prostration. The disease is, during the first week, of the nature of a bacteræmia, the organism being easily recoverable from the blood, the inoculation of which up to this time into a guinea-pig or a mouse causes a fatal infection. After the first week, however, the organism usually disappears from the blood of the human patient, and about this period agglutinins develop and attain their maximum between the fourth and the seventh week, after which they tend to fall, but persist in lesser degree often for many years.

From a surgical point of view the prognosis is good, although in about half the glands involved suppuration is liable to ensue and small foci of suppuration also occur along the course of the subcutaneous lymphatics. The disease is self-limited and runs a course of from six weeks to six months. The mortality ranges from 7 to 10 per cent. and is usually due to sepsis. One attack of the disease confers immunity.

Because of its occurrence amongst rodents and its convection by animal parasites, the condition has to be differentiated from bubonic plague. Tularæmia occurs most often amongst butchers, hunters, and those who come into closest contact with the infection-bearing rodents or with the wood-tick (*Dermacentor*). The patient will probably not be seen until the lymph-nodes are enlarged and the ulcer present on finger or hand, with perhaps the red streaks of lymphangitis up the forearm. A history of a preceding attack of chill with nausea, vomiting, fever or malaise should arouse suspicion. Laboratory infection of those working with the organism of Tularæmia is usually liable to occur, several cases being recorded both in this country and America.

With regard to treatment little need be said. The indications are to keep the part and the patient at rest, the ulcer clean, and to open abscesses as soon as the presence of pus can be detected. Care must be taken to maintain the nutrition of the patient. Blood transfusion, using if possible the blood of someone who has had the disease, will materially shorten the course.

Gonorrhœa.

Gonorrhœa is an infective process due to the action of a specific micro-organism, the *Neisseria gonorrhœæ* or gonococcus (Plate I., Figs. 5 and 6), and characterized, in its commonest form, by a discharge of pus from the urethra. The organism is a Gram-negative diplococcus, this fact being of great importance in diagnosis, since

most, though not all, of the diplococci with which it might be confounded retain the stain. Each coccus of the pair is usually kidney- or bean-shaped, the two lying with their concave surfaces towards one another. It may occur in large numbers in the pus, and in most cases it is found within the polymorphonuclear leucocytes. This is very characteristic, as also the fact that, even when only a comparatively small number of the cells may contain the organisms in their cytoplasm, those that do so are usually densely crowded with them (see Plate I., Figs. 5 and 6, in which some of the cells contain few or no cocci, but in others the diplococci can be seen clustered in the cytoplasm). The pus also contains desquamated epithelial cells, in or on which many cocci may often be seen, and varying numbers of the latter may also be found free.

Diagnosis.—For the detailed description of the methods of laboratory diagnosis of gonorrhœa, both microscopical and cultural, text-books of practical bacteriology should be consulted. In the **male,** especially in its more acute stages, the diagnosis can often be made at once by the microscopical examination of stained films of the discharge. At least three films should be made, to be stained by Gram's, by Leishman's, and possibly by other methods. When the discharge is abundant, the making of these preparations is usually a simple matter; but, if it is scanty, especially in certain chronic cases, such smears can best be made from the morning discharge before this has been washed away by the passage of urine; and it may be necessary to 'milk' the penis for this purpose. When the infection has passed its acute stage and may have reached the posterior urethra, prostate and seminal vesicles, massage of these *per rectum* should be performed, any discharge appearing at the meatus being collected in a suitable sterile vessel, and also specimens of urine obtained both before and after this procedure. If cultures are to be made, for diagnosis or for the preparation of an autogenous vaccine, it is essential that this should be done immediately by the direct inoculation of platinum-loopfuls of the discharge on appropriate special media, *e.g.* hydrocele-agar or whole blood-agar with a sufficiently moist surface, preferably previously warmed to body temperature. For a satisfactory diagnosis **in the female**—sometimes a matter of great difficulty—such cultural methods are often necessary, the material for these and also for microscopical examination being obtained by expressing some of the muco-purulent discharge from the urethra, and also by taking a swab from the cervical canal through a sterile speculum, after the contaminating surface discharge has in both instances *been thoroughly wiped off* with surgical swabs. It must be particularly emphasized that, except in the vulvo-vaginitis of young children, it is practically always useless and even misleading to submit for examination for the gonococcus films or swabs of the general leucorrhœal vaginal and vulvar discharge, which contains enormous numbers of mixed organisms, some of them not unfrequently morphologically resembling the gonococcus, which itself may be present in this general discharge only in such minimal numbers as to escape detection. The **complement-fixation test** may also be used as an aid to the diagnosis

of gonococcal infections. In suspected cases in either sex, where examination by the above methods has failed to reveal the presence of the gonococcus, a positive reaction is usually obtained if the infection has spread beyond the anterior urethra, and this reaction may persist for one or two months, or sometimes considerably longer, after the cocci have disappeared from the discharge. In the female, weaker reactions are obtained than in the male. In either sex a positive reaction is diagnostic of the presence or recent existence of gonococcal infection, but a negative reaction, especially in the female, does not by any means invariably indicate freedom from infection. It must be remembered, however, that the administration of a gonococcal vaccine also produces a positive reaction with this test.

(I.) **Gonorrhœa in the Male.**—The primary lesion is an acute catarrhal inflammation of the anterior portion of the urethra, rapidly becoming suppurative, and likely to spread back to the deeper portions of the urethra, the prostate, bladder, seminal vesicles, or epididymis. Important alike in prognosis and treatment is the fact that the gonococcus is found, not merely on the surface and in the mucous membrane of the urethra, but also deeply in the submucous coat and in the mucous glands and glandular lacunæ. The infection may remain limited to the genito-urinary system, but secondary infection by way of the blood-stream may take place, especially of joints (gonorrhœal rheumatism); and, in very rare cases, ulcerative endocarditis or even meningitis has supervened.

The Symptoms of Acute Gonorrhœal Urethritis commence usually in from two to eight days after infection. Most commonly the discharge appears about the third or fourth day, being preceded by itching of the meatus and a scalding pain on passing urine. The lips of the meatus are congested and swollen, and the discharge, which is at first thin and mucoid, soon becomes thick, abundant, and yellowish in colour. This stage lasts for a variable time, and is sometimes associated with a good deal of dragging pain in the back and loins, together with some constitutional disturbance and fever. The bowels are usually constipated, and the appetite impaired. Hæmorrhage from the urethra may result from the congestive swelling of the mucous membrane, which, together with the pain on micturition, may also lead to retention of urine.

If the condition is neglected, and often even in spite of treatment, the inflammation spreads backwards, giving rise to what is termed a **Posterior Urethritis.** This generally becomes evident about the end of the second week, and is characterized by frequent and painful micturition, a sense of pain and heaviness in the perineum, possibly a little blood in the urine, and a general feeling of depression. This extension backwards is always serious, since it is liable to be followed by an acute prostatitis, vesiculitis, or an epididymitis. These complications will be described elsewhere, but very frequently the extremely common condition of **Chronic Gonorrhœa or Gleet** supervenes, in which a more or less abundant discharge continues for some time without any troublesome symptom other than occasional scalding pain on passing urine. The gleety discharge is often thin and muco-purulent,

and may be so slight as merely to cause the lips of the meatus to stick together, or may be evident only on squeezing the urethra after a night's rest. This may last for a long time, perhaps years, and it must be remembered that even in this stage the disease can still be transmitted to others. Gleet is sometimes due to invasion of deep lacunæ, or to an ulcerated or granular condition of some portion of the mucous membrane; the discharge is then yellow, and the urethra is tender on the passage of a sound; the presence of the local focus can be recognized by the urethroscope. In most cases gleet arises from chronic prostatitis, a condition not uncommonly associated with chronic infection of the vesiculæ seminales. The latter condition may be recognized on rectal examination, whilst, when the prostate is involved, flocculi of mucus in the shape of worm-like threads may be detected in the urine, especially after massage of the gland by the finger introduced into the rectum.

When the disease has lasted for a considerable time, or after repeated attacks, a certain amount of peri-urethral infiltration is certain to follow, and a stricture of the urethra may result; this may also be due to the cicatrization of the ulcerated and granular patches in the urethral wall, described above.

The exact source of a chronic urethral discharge is by no means easy to ascertain. Examination of the urine by the two-glass test, which was formerly relied on, is in reality quite useless, inasmuch as all the discharge accumulated in the urethra is washed out into the first. If, however, the urethra is cleansed by passing a portion of the urine into a glass, and then thorough prostatic massage is carried out, the examination of the first urine passed afterwards will be of great significance; if it contains pus and gonococci, then infection of the posterior urethra is present. Examination by the urethroscope or endoscope is, however, much more reliable and useful. The instrument consists of a metal tube fitted with electric illumination in such a way as to render visible the walls of the urethra, which should be distended with air by a bellows. A commencing stricture can be easily recognized, as also ulcerated areas, patches of granulations more or less polypoid, etc.; and the use of this instrument also enables suitable local treatment to be undertaken.

Every purulent discharge is not necessarily gonorrhœal, since a simple urethritis may follow connection with a woman who is suffering merely from a non-gonococcal form of leucorrhœa. In these cases infection may be due to ordinary pyogenic cocci, or possibly to *Bact. coli.* Although the history may suggest a simple urethritis, the diagnosis can be made only by the microscopical examination of the discharge and, as already noted, cultural examination may also be required. It must be remembered, however, that gonococci are capable of remaining in a latent or passive state for a very long time in the folds or crypts of a mucous membrane, and hence a person who has once suffered from it may be capable of transmitting the disease, although no obvious evidence of its existence may have been found. Moreover, in a gouty patient, a highly acid condition of the urine, especially if it is loaded with uric acid crystals, may light up

into activity a urethritis which has been quiescent for some time, as may also an over-indulgence in alcohol in a patient apparently cured.

The practitioner is not unfrequently consulted as to the advisability or otherwise of marriage after an attack of gonorrhœa; the mere cessation of the discharge is not sufficient to warrant such a step. The only reliable test is to light up a fresh attack of urethritis by the injection of some suitable chemical irritant, *e.g.* a solution of nitrate of silver (1 in 100) or pilocarpine hydrochloride (1 in 400), and to examine the discharge bacteriologically for the presence of gonococci. Lugol's iodine solution has also been used for this purpose, combined with an intracutaneous injection of vaccine.

Prophylaxis.—Whilst it is obvious that the only effective means of avoiding infection with a disease so easily contracted as gonorrhœa is the abstinence from exposure, and that for this purpose moral restraints must be relied on, yet whilst human nature remains more or less constant in type, such abstinence is unlikely to be general, and venereal disease will persist, with all its crippling and mutilating results, which are only too liable to spread to innocent victims. From the point of view of the State, to protect these, and also the exposed individual, by the adoption of simple precautionary measures, is necessary. The fact that the infection immediately after exposure may still be more or less superficial, and only penetrate to the deeper parts after an appreciable interval, is the key to prophylactic treatment, which consists in the effective washing of the parts with soap and water, followed by a 1 in 2,000 solution of potassium permanganate. Attention should be directed especially to the thorough cleansing of the frænum and meatus, the lips of which should be opened so as to allow some of the solution to enter. The use of calomel ointment to smear over the parts has also been advised, but it is a comparatively weak antiseptic, and the method advised above has been proved to be efficient in the majority of cases.

Treatment.—Recent work tends to show that at last an effective remedy has been obtained in drugs of the *sulphanilamide* group. The most popular remedy at present is 'uleron,' which is given in doses of two tablets three or four times daily for three days. After an interval of ten days a second course may be given, and even a third if the case does not appear cured. About 65 per cent. of the acute and 70 per cent. of the chronic cases appear to be cured with this treatment. At the same time general measures should be adopted. In acute cases it is wise to keep the patient in bed for a few days on a fluid non-stimulating diet which excludes meat, alcohol, tea, and coffee; he is permitted to drink barley-water and milk and soda-water; alkalies and purgatives are administered with tincture of hyoscyamus as a sedative, and all local interference is avoided. A hot bath will usually overcome the difficulty in micturition; every effort must be made to avoid the necessity of the introduction of a catheter. At the end of a few days, when the symptoms have subsided, the patient may be allowed to take quiet exercise or to go about his ordinary duties, but the scrotum should be supported in a suspensory.

Drainage.—It is a controversial point whether irrigation should or should not be carried out in the acute stages. It is probably better that it should be reserved for the subacute (after six weeks) and chronic cases, and when started should include the whole lower urinary tract, including the bladder as well as the urethra, with a weak solution of potassium permanganate (commencing with 1 in 8,000, and increasing the strength as the infection becomes more chronic or approaches a cure, when a 1 in 4,000 solution may be used). The apparatus required is a receiver to hold about 2 pints connected by a rubber tube with a glass cannula protected to prevent splashing backwards, although a simple blunt-ended cannula quite well suffices. The lotion is placed in the receiver at a temperature of 104° F., and provision is made for the escape of the injected fluid after use into a suitable vessel. The patient is first instructed to micturate so as to wash away all discharge lying in the urethra. At first the receiver is kept only about two feet above the patient's pelvis, so as not to force open the compressor muscle and carry the fluid into the posterior urethra; the anterior portion is alone washed out two or three times a day, but the force employed is sufficient to dilate the tube and open up the crypts and lacunæ so as to bathe them effectively with the antiseptic lotion. After a day or two the patient is encouraged to fill his bladder with the lotion; this is best accomplished by raising the receiver to a height of about three feet above the pelvis and instructing him to breathe easily and to attempt to micturate whilst the fluid is being injected; the compressor will thus become relaxed, and the fluid enter the bladder. After a little practice the patient will be able to distend his bladder in this manner, and thus even if a few cocci are carried back they are floating in a large bath of antiseptic lotion in which they are comparatively harmless. All the crypts and recesses of the urethra, both superficial and deep, are by this means opened up and brought into contact with an abundance of antiseptic fluid, which is expelled after being retained for twenty or thirty seconds. The effect of this treatment is most satisfactory, the discharge rapidly diminishing, but it must be persisted in until all discharge has ceased.

After the acute stage has subsided, and if there has been evidence of an acute prostatitis, massage of the prostate and vesicles should be started so as to expel infective material which may lodge in those organs. It should be carried out twice weekly for four or six weeks.

The treatment of a case of **Gleet**, which has not responded to chemotherapy, is often a matter of difficulty, but as more efficacious methods for dealing with the acute stage are enforced, gleet should become much less prevalent. The first principle of treatment consists in finding out the actual nature and site of the lesion, and to this end the urethroscope is used. If patches of granular urethritis are present or localized ulcers, topical applications of nitrate of silver in strengths up to 5 per cent. should be made. In the absence of these lesions the gonococci are probably to be found in the lacunæ of the urethra, the crypts of the prostate or the seminal vesicles. These must be emptied methodically by dilatation of the urethra with some such

appliance as Kollmann's dilator (Fig. 43), or by massage of the prostate and seminal vesicles two or three times a week; the discharge thus expressed is washed away and the urethral canal cleansed by intravesical injections of permanganate of potash. Occasionally, injections of silver salts into the urethra so as to reach the posterior portion are beneficial; the simplest method is to pass a measured length of rubber catheter (about 7½ inches) into the urethra and then inject the fluid. A drachm or two of a 1 in 1,000 solution of silver nitrate injected twice or thrice a week will be sufficient. The diet should be simple and non-stimulating; alcohol, tea, and coffee should be avoided; undue exercise, especially after the massage and injections, forbidden; and absolute sexual continence enjoined, so as to prevent the spread of the infection. Marriage necessarily is prohibited until the condition is completely cured.

An increase in the powers of the body fluids or tissues to deal with the gonococci may be produced by vaccine treatment and diathermy.

(1) **Vaccine Treatment of Gonorrhœa** has proved to be of considerable value, especially in the subacute stage when the discharge is

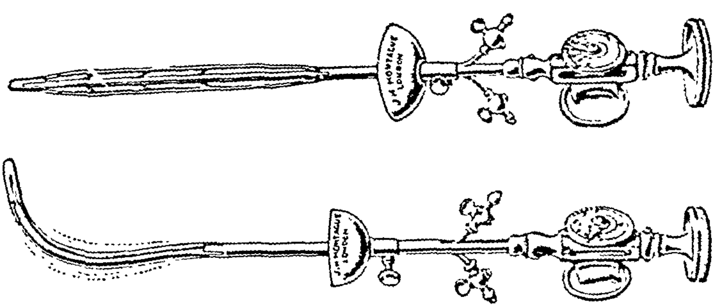


FIG. 43.—KOLLMANN'S URETHRAL DILATORS, AS EMPLOYED FOR THE ANTERIOR AND POSTERIOR PORTIONS OF THE URETHRA RESPECTIVELY.

diminishing. It is often of great assistance in the treatment of gleet, as also in many of the complications, *e.g.* of the joints and fibrous tissues. It appears that some strains of cocci are of greater value than others in assisting immunity, and therefore a stock vaccine, if used, must be polyvalent; but an autogenous vaccine is always preferable, the usual initial dose being 5 million, increased at about weekly intervals, slowly or more rapidly, according to the result of each preceding reaction. Furthermore, the infection usually becomes a mixed one, such organisms as *Staphylococcus albus*, streptococci (*e.g. Str. fæcalis*), diphtheroid bacilli, etc., and sometimes *Bact. coli*, being often present along with the gonococci, and, especially in many old-standing cases, eventually even coming to replace these. These organisms, if present, should therefore also be included in the vaccine.

(2) **Diathermy** is now much used in treating some of the results of gonorrhœa. Special textbooks must be consulted for descriptions of the exact technique, and for the various hypotheses as to its method

of action upon the tissues and the micro-organisms. The chief conditions for which such treatment is advised are subacute or chronic urethritis, prostatitis, and vesiculitis. With it inflammation of the epididymis and testis usually rapidly subsides, and gonorrhœal arthritis may be benefited.

Complications due to Direct Extension.—**Balanitis,** apart from gonorrhœa, is of frequent occurrence in patients with long foreskins, and is then ordinarily due to pyogenic organisms. It often, however, supervenes in gonorrhœa, and, as a secondary result, inflammation of the lymphatics of the penis and inguinal bubo may follow. Sometimes this inflammation results in the development of red papillomatous outgrowths, known as **gonorrhœal warts,** which are found mainly on the glans penis, but occasionally on the preputial margin.

Lacunar Abscess arises from infection of one or more of the glandular lacunæ with the gonococcus or accompanying pyogenic organisms. A tense painful swelling forms along the floor of the urethra, which may project into the passage and discharge either into the urethra, or externally, or both; in the latter case a **penile fistula** will result. The abscess should be opened as early as possible from without, so as to prevent the latter occurrence, which is often very difficult to treat. If a fistula forms within a short distance of the meatus—a common situation—it seldom heals of itself, but may in some cases be closed by an application of the electro-cautery or a weak solution of nitrate of silver. If, however, it remains intractable, the fistula should be laid open into the meatus. When it occurs in the body of the penis, a plastic operation is usually required; it consists in paring the edges and dissecting up the skin on either side so as to bring it together in the median line.

Chordee, or painful erection, results from inflammatory infiltration of the corpus spongiosum or one of the corpora cavernosa, so that the penis, when erect, is bent downwards or to one side. It is exceedingly painful, and most marked at night when the patient becomes warm in bed. It is best prevented by the use of bromide of potassium or other sedative at bedtime, and when present may be treated by cold applications.

Inflammation of Cowper's Glands may in some cases give rise to deep suppuration in the perineum, and unless treated early by incision may lead to a urinary fistula.

Inflammatory conditions involving the prostate, seminal vesicles, epididymis, and bladder, caused by gonorrhœa, are discussed elsewhere (see index).

(II.) **Gonorrhœa in the Female.**—Gonorrhœa is frequently an unsuspected source of uterine and pelvic trouble. Apart from sexual intercourse, the disease may also be contracted from the use of infected towels, garments, etc., and even from the infected seat of a water-closet. The primary lesion is usually either in the **urethra** or in the **cervical endometrium,** or in both. **Vulvitis** is by no means uncommon, but in the adult a gonorrhœal vaginitis is unusual. Sometimes discharges from the cervix accumulate in the vagina and undergo septic changes, producing a simple vaginitis, but the gonococci do not readily

attack the vaginal mucosa, and for this reason the presence of gonorrhœal infection in the female is often overlooked. In children a true gonorrhœal **vulvo-vaginitis** occurs, sometimes in epidemic form, *e.g.* in girls' schools and other institutions.

Symptoms and Complications.—The symptoms in acute cases are those of heat and burning about the genitals, combined with a purulent discharge and painful micturition. The **urethra** can be seen and felt to be swollen, its orifice is red and congested, and pus can be expressed from it. If the **cervix** is involved an endo-cervicitis results. The uterus becomes congested and painful, with a blood-stained discharge; severe backache is felt, and perhaps some tenderness on pressure over the lower part of the abdomen. In the more chronic cases little may be noted except that the periods are painful, and that there is a certain amount of leucorrhœa, with occasional attacks of discomfort and frequency of micturition.

In all cases the inflammation is likely to spread, either to the bladder, or up the uterus to the Fallopian tubes (**salpingitis**), ovaries, the cellular tissue of the broad ligaments, etc., or to the peritoneum—in which case the inflammation may be localized, producing adhesions around the fimbriated extremities of the tubes, and these are often an important cause of sterility. Peritonitis is not an uncommon complication, but is more favourable than the type caused by other organisms in that it tends to remain localized to the pelvis.

Treatment follows along the same lines as in the male, *viz.* by bathing the parts frequently with an abundant supply of weak permanganate of potash (1 in 2,000). The patient lies on her back in the lithotomy position, and the vagina is filled with the lotion from a douche can, the fluid being retained for a time. It may be desirable to apply tincture of iodine or a solution of nitrate of silver to the cervix through a speculum, or to the urethra. In addition, treatment by diathermy is very valuable, especially in the chronic cases. It should be applied to the urethra and cervix by means of special electrodes, the temperature and duration of treatment being gauged by that degree which causes discomfort to the patient when tried firstly in the urethra. Vaccines should also be tried.

(III.) **Gonorrhœa in Either Sex—Complications arising from Direct Transmission of the Infection.—Gonorrhœal Proctitis** sometimes results in the female from infection of the anal region, etc., by the discharge which escapes from the vulva, whilst in both sexes it may be due to unnatural practices. It is characterized by tenesmus and a thick muco-purulent discharge, and is treated by injecting lotions of acetate of lead and opium, or of boric acid. Abscesses, fistulæ, stricture, etc., will require appropriate treatment.

Gonorrhœal Rhinitis has also been seen in a few cases. It leads to an abundant discharge of pus, and should be treated by warm soothing injections, followed after a time by dilute astringents. **Stomatitis**, with the presence of whitish patches surrounded by reddish zones on the buccal mucous membrane, gums, tongue, tonsils, etc., is a rare complication, which may be treated with a potassium permanganate mouth-wash.

Gonorrhœal Conjunctivitis.—For this serious complication see Chapter V.

Complications resulting from General Absorption.—**Gonorrhœal Affections of Joints** are not uncommon sequelæ, arising usually in the subacute stage of the disease. The knee is affected in about 40 per cent., the wrist in 20 per cent., and the fingers in 10 per cent. Much periarticular thickening takes place, and this leads to a marked limitation or false ankylosis of the joints. In some cases suppuration occurs, and leads to a knee ankylosis.

Gonorrhœal Fibrositis.—Any muscular, tendinous, ligamentous, or aponeurotic tissues may become inflamed and painful during the course of an attack of gonorrhœa. In the case of involvement of the ligaments supporting the arch of the foot, the patient must not be allowed to walk, otherwise the arch may give way and a permanent flat-foot result.

Gonorrhœal Scleritis, or inflammation of the deep subconjunctival fibrous tissue, is a rare affection, arising quite independently of gonorrhœal conjunctivitis. It is characterized by marked subconjunctival redness, the globe of the eye becoming distinctly tender. Local applications of atropine are required and, if need be, leeches to the temples. For descriptions of **Iridocyclitis,** rare as an early, but fairly common as a late, complication, and usually associated with gonorrhœal arthritis, and for other rarer gonococcal infections of the eye, textbooks on ophthalmology should be consulted.

Gonorrhœal Endocarditis, etc.—Occasionally the cardiac valves become infected and inflamed, and an ulcerative endocarditis due to gonococci has been observed. More rarely a septicæmic infection may occur.

Gonorrhœal pyæmia, a condition of great rarity, is characterized by a formation of secondary abscesses in various parts of the body, containing the gonococcus. Gonorrhœal meningitis is another extremely rare complication of the disease.

Soft Chancre or Chancroid (*Ulcus Molle*).

Soft Chancre is a local infective venereal lesion, which is rarely seen elsewhere than on the genital organs. It is due to a specific bacillus, which was first described by Ducrey, and which occurs in the form of short chains consisting of slender rods, which are Gram-negative and do not form spores. The organism can be cultivated, though with difficulty, and in the lesion ordinary pyogenic organisms are often also found. Infection is followed by a typical series of events. A red papule appears in a few hours, and in two or three days a vesicle, surrounded by a zone of angry hyperæmia, is seen. The serum within the vesicle soon becomes turbid, and by the fourth or fifth day a fully-developed pustule is present; as soon as the cuticle is lost, an ulcer forms with cleanly-cut edges and a sharp, distinct outline, gradually increasing in size up to perhaps half an inch or a little more. Around the ulcer there is an outer red areola, within which is an inner yellowish-grey zone, whilst the floor of the ulcer

itself shows 'little red cup-like points visible under a lens' (P. Fernet). Such a sore may occur upon any part of the penis, but more especially the prepuce and glans, or the corona glandis, and in the case of the female about the vulva. It sometimes develops within the meatus, producing a considerable discharge which may simulate that of gonorrhœa. The lesion is usually very painful and tender. The exudate is highly infective, and if inoculated elsewhere on the patient produces a typical sore, showing that the condition is purely local, and that no constitutional immunity results from its presence. Frequently several soft sores are present at the same time, and the discharge from one chancre is very likely to produce a similar affection ('satellite' chancre) on any cutaneous or mucous surface brought into contact with it; *e.g.* it may spread from prepuce to glans, or *vice versa*, or from one lip of the vulva to the other. It is a curious but well-authenticated fact that soft chancres are rarely seen on any part of the body other than the genital organs. The discharge from a true syphilitic chancre may produce a localized pustule on auto-inoculation, but no typical primary hard sore.

Complications of the typical soft chancre may occur. Thus, if a long foreskin is present, the discharge may be retained beneath it, and extensive ulceration follow, which may even result in the glans protruding through the upper part of the prepuce, which drops beneath it. If the frænum is involved, hæmorrhage may supervene from ulceration into a branch of the artery in it. When there is much inflammation, the base of the sore becomes indurated and infiltrated, somewhat resembling the Hunterian syphilitic hard chancre. Not unfrequently a co-existing syphilitic infection may complicate the diagnosis, and it is usually advisable to examine such cases bacteriologically and serologically with this possibility in view. The sore then runs a longer course, does not heal, even if kept clean, and after a time the patient, if untreated, develops the characteristic signs of syphilis.

The neighbouring **Lymph-nodes** practically always become enlarged and tender, and the process is very liable to terminate in suppuration, constituting a bubo. Two forms of this affection are described: (*a*) The simple bubo results from the absorption of ordinary pyogenic organisms from the abraded surface. The pus in this case, if inoculated elsewhere, may produce a pustule, but not a true soft chancre. The process is usually limited to the lymph-nodes themselves. (*b*) The virulent bubo is due to the absorption, not only of pyogenic organisms, but also of the specific bacilli, so that the pus, if inoculated, produces a typical soft sore. In these latter cases suppuration occurs not only in, but even more abundantly around, the lymph-nodes (periadenitis), so that the skin becomes considerably undermined, and the wound produced by opening the abscess may take on the form of a large soft chancre in the groin, in the centre of which is seen the lymph-node only slightly enlarged. The process is often slow, and a good deal of cutaneous redness is present with but little pus.

Diagnosis of soft chancre and of the buboes secondary to it is sometimes a matter of considerable difficulty, especially its differentiation from lymphogranuloma inguinale. For this purpose, in addition to the

isolation and identification of the specific bacillus, two methods may be employed: (1) The re-inoculation intradermally of the patient himself with living infective material from his own lesion, reproducing the typical soft sore from which Ducrey's bacillus is recovered; and (2) the intradermal injection of a vaccine ('Dmelcos') giving a positive cuti-reaction.

Treatment with stock vaccine of Ducrey's bacillus ('Dmelcos') administered intravenously, and which may also be applied as a local dressing, should be preceded by such local measures as cleansing the sore, and especially its undermined edges, *e.g.* by playing a strong jet of hydrogen peroxide upon it, followed by eusol, repeated if necessary after brushing off any loosened discharge. The surface may then be swabbed with tincture of iodine (mitis) and dressed with sterile gauze. If a purulent discharge is still present, the spraying with peroxide and eusol is repeated. If it then remains clean, it may be sprayed with sterilized, freshly made, or collosol tannic acid, allowed to dry and remain exposed to the air. If the formation of a bubo threatens, the crusts are soaked off and eusol applied. Where much balanitis exists, it may be necessary to slit up the prepuce, but circumcision should not be undertaken until the sores have healed. In some, but not in all, cases a 3 per cent. solution of N.A.B. (see p. 159) has been found efficacious.

Buboes are treated in the early stages by keeping the patient at rest and applying fomentations, when resolution sometimes occurs. If suppuration ensues, the abscess should be incised vertically, so as to allow free exit to the pus even when the patient is sitting, the cavity being subsequently dressed by packing it with gauze impregnated with eusol or lotio nigra.

Climatic Bubo, Lymphogranuloma Inguinale, etc.

This is a disease which has been described by many names, of which **lymphogranuloma** is the most usual. It is due to a filter-passing virus and is transmitted venereally. The disease does not appear to be indigenous to Great Britain, but is found usually in seamen who have contracted it abroad, *e.g.* in the West Indies, China, some parts of Africa, also in the United States. The antigen used for the intradermal test devised by Frei is obtained by aspirating blood-free pus from the affected inguinal lymph-nodes of a known case of the disease in whom tubercle, syphilis, gonorrhœa, ulcus molle, etc., have been excluded, the fluid so obtained being diluted with saline and sterilized at 60° C. In the male, the primary lesion usually occurs about the coronary sulcus as a transitory herpetiform ulcer or as a nodule, appearing a few days after coitus, and followed in from about one, two, or three weeks or longer by swelling of the inner or median group of inguinal nodes on one or both sides. The glandular swelling may be slight or marked, with or without suppuration, and sometimes accompanied by prolonged fever, which may even simulate enteric or endocarditis. The nodes show endothelial proliferation, usually with some giant-cell formation not unlike those of tubercle and syphilis. De-

generative changes, cellular infiltration, and micro-abscess formation usually follow, the process having been described as a 'glandular granulomatosis of progressive type,' and in a few cases an elephantiasis of the genitals supervenes from blocking of the lymphatics. A hyperplastic fibrosis of the perirectal tissues, in some cases progressing to stricture of the rectum, may supervene, especially in the female, owing to the spread of the infective process from the vulva and vagina by way of the lymphatics. For a note on the differential diagnosis of lymphogranuloma inguinale from soft sore and from syphilis see pp. 143 and 144, and in this connection it must be remembered that mixed infections of these venereal diseases are by no means rare. The treatment which is most frequently used is intravenous medication with antimony and pot. tartrate, but it is not curative. For rectal stricture a colostomy provides great relief and improves the local condition. Recent publications tend to show that sulphanilamide medication is likely to prove a very effective remedy in the treatment of the disease.

Syphilis.

Syphilis is a specific disease due to the spirochæte discovered by Schaudinn and Hoffmann in 1905, now termed *Treponema pallidum* (formerly *Spirochæta pallida* and sometimes *Spironema pallidum*) (Plate V., Figs. 1 and 2). It can be cultivated, as discovered by Noguchi, in a mixture of agar and ascitic fluid containing a bit of sterile fresh animal tissue, *e.g.* rabbit's kidney, under strict anaërobic conditions. Morphologically, it is a very delicate spiral filament, having some eight to twelve usually very regular short deep curves; its ends are sharply pointed and tapering. Its length varies, but on an average is about equal to the diameter of a red blood-corpuscle or a little more, and each whorl occupies about 1 μ. The common *Tr. refringens*, which is frequently found in the mouth, tonsils, etc., is larger, broader, has blunter ends, and a smaller number of less regular whorls.

The specific organism can be detected in the great majority of all cases of syphilis; and it may be present in enormous numbers in the lungs, liver, spleen, and other viscera of still-born syphilitic fœtuses. In acquired syphilis it may be demonstrated in the earliest stages of the sore which precedes the typical primary chancre, or in scrapings from it; in the secondary stage it occurs in the skin-lesions, or in the fluid of blisters raised near them, in the lymph-nodes and in the spleen, and has been demonstrated in the blood, though rarely; in the tertiary stage it has been found in small numbers in gummata and other specific lesions, but in the majority of cases at this stage it can be demonstrated only with great difficulty and after prolonged search; especially is this the case in the so-called parasyphilitic affections of the nervous system, now usually described as neurosyphilis, such as general paralysis or locomotor ataxia.

Syphilis occurs in man, but may be artificially inoculated into the higher apes, which develop a disease comparable in most of its features with human syphilis, and experiments on these animals have yielded

results of much clinical value. The disease has been transmitted by material obtained from the human subject in all stages, *e.g.* the blood, the semen, discharges from the primary sore, from secondary lesions, and even from gummata. After such experimental inoculation, the incubation period is from three to four weeks, and then an indurated nodule appears which undergoes ulceration, and is accompanied by enlargement of lymph-nodes. Mild secondary symptoms usually follow, but in apes tertiary manifestations have not been observed. Inunction of calomel ointment locally can prevent infection, even up to twenty hours after inoculation; but excision of the inoculated area has proved useless except when undertaken within eight hours after infection. The rabbit has also been much used for the experimental transmission of the organism, the inoculation being made into the eye or testis.

The most important methods for the **Laboratory Diagnosis** of syphilis are the demonstration of the spirochæte and the Wassermann reaction. Among other valuable though less important methods the Meinicke clarification reaction and the Kahn flocculation test are the most useful; whilst the examination of the cerebro-spinal fluid is often of great importance, especially in the later, but sometimes also in the less advanced, stages of the disease. *Tr. pallidum* can usually be found without difficulty in the serum which oozes from the surface, and especially from the margins of the chancre after the surface has been thoroughly cleansed with saline, firmly rubbed with alcohol and again with saline; or, after the preliminary cleansing, it may be scarified—bleeding being avoided, or if it occurs, the blood being wiped off until serum alone exudes. This is then transferred directly with a platinum loop to a ringed slide for examination by dark-ground illumination and other films made in various special ways, or it is collected in a capillary tube for transmission to the laboratory. Puncture of neighbouring enlarged lymph-nodes may also be employed, a little sterile saline being first placed in the syringe in order to wash out the small amount of gland-juice collected in the needle. Long before the sore has taken on a typical appearance the spirochætes may be thus demonstrated and the diagnosis made. No antiseptic should be applied to the sore before examination. Three methods of demonstration may be employed: (1) The material may be examined fresh under dark-ground illumination. This is considered by many to be the best method, the organisms being easily seen and their characteristic movements observed. (2) Appearances somewhat similar can be secured by mixing the exudate with very fine fluid Indian ink, spreading it out into a film, and allowing it to dry on a slide. Here also the organisms appear colourless on a dark ground, but, of course, there is no movement. This is a simple and quick method; or the material may be mixed wet with 2 per cent. Congo red, dried, blued by exposure to the fumes of strong hydrochloric acid—with no washing at any stage—the spirochætes being silhouetted colourless against the blue background. (3) There are numerous staining methods, most being modifications of Romanowski's. Processes depending on the reduction of silver salts are also used, both for films and sections.

In the **Wassermann reaction**—a complement-fixation test—we possess a test which, when positive, is of the greatest value. In syphilis, this reaction is not established immediately, but may first show itself in two, three, or four weeks after the appearance of the primary sore. In some cases it may be delayed till the fifth or sixth week, or even later. It is, therefore, essential to examine a suspected sore itself for *Tr. pallidum*, before local antiseptic treatment has been commenced. A positive diagnosis may thus be made at once in many cases; and if there are reasonable clinical grounds for believing the case to be syphilitic, and especially if it is possible thus to demonstrate the presence of the spirochæte, it is bad practice to await the establishment of a positive Wassermann before commencing treatment—the results of **immediate** treatment being infinitely better than if delayed until the Wassermann reaction has developed. Moreover, in this early stage, a single negative Wassermann reaction is of little value by itself, and the test may have to be repeated several times.

In untreated cases in the secondary stage, the Wassermann reaction is practically uniformly positive, and the result of the test may, in the vast majority of cases, be taken as an accurate indication of the presence or absence of syphilitic infection.

In the tertiary and late stages, a negative Wassermann reaction is never absolutely conclusive. In many cases, a positive reaction may still persist; but in a certain proportion, including older standing congenital cases, it may become feeble or absent. In a not inconsiderable proportion of old-standing nervous cases, the **cerebro-spinal fluid** may give a positive result, although the reaction in the blood may be slight or have completely disappeared.

For purposes of diagnosis, a positive reaction may, in some cases, be induced by a small 'provocative dose' of salvarsan, etc. It must be clearly remembered, however, that a positive reaction merely proves the presence of a syphilitic infection in the body; it does not prove that a given lesion is syphilitic.

The **Clinical History** of syphilis varies widely in different cases according to the virulence of the infection and the degree of resistance of the tissues, but the division into three stages, as suggested by Ricord, though artificial, and though these stages often overlap, is convenient for purposes both of description and treatment. The **primary** stage includes a varying period of incubation, and the appearance of a sore, usually known as a 'hard chancre.' This is followed in the course of a few weeks by signs of **general** infection, referred mainly to the skin, mucous membranes, and lymph-nodes, comprising the **secondary** stage. After a variable time, perhaps extending to many years, during which definite symptoms may not be in evidence, **tertiary** manifestations (gummata, etc.) may show themselves in any part of the body.

Mode of Infection.—Acquired syphilis is almost always due to infection of the genital organs by the spirochæte transmitted by sexual connection. Cases, however, also occur in which the disease is acquired otherwise, *e.g.* by direct or indirect contact with syphilitic

lesions, and then the primary lesion is often located on some other part of the body (**extragenital chancres**). Thus, the lip may be infected as a result of drinking out of the same glass or smoking the same pipe as a syphilitic patient, or by kissing. It has been conveyed from person to person by imperfectly sterilized dentists', hair-dressers', and manicurists' instruments; and to doctors, dentists, and nurses in the course of their work. The spirochæte is a delicate organism, and quickly loses its virulence outside the body. This probably explains the rarity of indirect infection. The disease is not equally infectious in all its stages; in the primary stage the discharge derived from the chancre will alone convey the contagion; in the secondary period the spirochæte is present in the blood, and consequently in all pathological exudates, as also in the semen. It is uncommon, but by no means impossible, for infection to be conveyed by patients in the tertiary stage.

The stage of **Incubation** lasts for a variable period, extending from two to six weeks; as a rule, evidences of induration of the sore can be detected about the third week. Removal or destruction of the local lesion has not the slightest influence upon the progress of the case unless it is undertaken immediately after infection, or unless the patient is being treated by salvarsan or one of its substitutes. Many spirochætes are enclosed within the chancre, and as these are inaccessible to the drug, it is advisable to remove them by operation. During the incubation period the local sore may heal over superficially, if it is purely syphilitic; and nothing further may be noticed until the typical induration manifests itself. Not infrequently, however, pyogenic infection is superadded, or, but much more rarely, lymphogranulomatous infection, or a soft chancre may also be present; in the two latter cases the lesions do not heal satisfactorily, and the base of the ulcer becomes indurated after a time. A moderate enlargement of the spleen has recently been described as occurring in a large proportion of cases some fifteen days before the appearance of the hard chancre, rapidly subsiding under appropriate antisyphilitic treatment.

I. **The Primary Stage** of syphilis is characterized by the development of a sore, associated with enlargement of the neighbouring lymph-nodes. The sore is most frequently situated on the prepuce, rather more frequently on the inner than on the outer aspect; it is common in the sulcus between the glans and prepuce; or may occur on the glans itself or on the frænum; but no part of the male genital organs is exempt. In the female it is most frequently to be found on the inner aspects of the labia majora or nymphæ, but it often causes so little inconvenience as to be overlooked.

The primary sore does not invariably present the same appearance, although it is typically characterized by a certain amount of infiltration and induration. The following are the chief forms in which the chancre manifests itself: (*a*) The **desquamating papule** is a slightly elevated spot, which is irritable, of a dusky colour, and free from ulceration. It is usually small, hard, and its surface covered with epithelial scales. If exposed to friction or to the irritation of re-

tained discharges, ulceration is very liable to occur, with at first but little induration. Unless such ulceration takes place, the disease may run its course unobserved, and thus a patient becomes syphilitic without being able to trace the time or source of infection. (*b*) The **indurated, hard,** or **Hunterian chancre** is that most commonly seen; it results from the irritation of a papule, or is developed in association with a soft sore. Should the initial surface abrasion have healed, a localized mass of almost 'cartilaginous' hardness forms in the cicatrix, closely adherent to and invading the cutis; but, if a soft sore has first developed, the surface remains ulcerated more or less deeply, with a well-defined margin, though the base becomes indurated (Fig. 44). In some cases there may be but little elevation

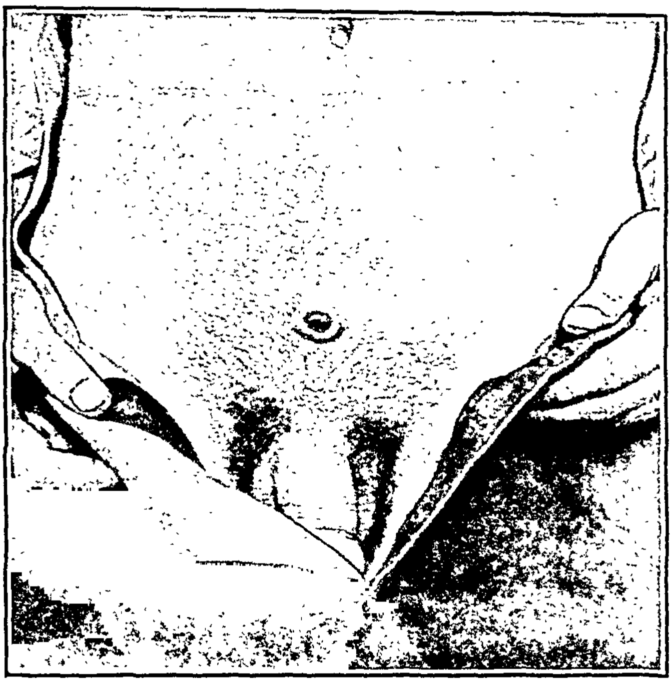


FIG. 44.—HARD CHANCRE OF ABDOMINAL WALL IN SUPRAPUBIC REGION.

of the lesion, and the surface is free from ulceration, constituting the variety known as the 'parchment induration' of Ricord, and most frequently seen on the glans penis. Where, however, the prepuce or body of the penis is involved, the induration is more diffuse, owing to the laxity of the connective tissue. When affecting the base of the prepuce, the induration usually spreads transversely, producing a collar-like mass, which on retraction of the part rolls back *en bloc* in a very characteristic manner. When the orifice of the prepuce is involved, the part becomes diffusely infiltrated and hard, so that retraction is impossible, and a form of phimosis is thus acquired. Examined microscopically, the new formation consists merely of a mass of round and spindle cells packed closely together, with a certain amount of intercellular fibrous tissue, giant cells, usually

smaller in size than those characteristic of tubercle, being sometimes seen. The blood-supply of the part is scanty, a fact which explains the readiness with which ulceration occurs. It is all-important, however, to remember that a diagnosis of syphilis can be made by the microscopical demonstration of the spirochæte long before this typical induration appears, and if such early diagnosis is made, and effective treatment commenced immediately, the likelihood of a complete cure is much greater and the necessary course of treatment less prolonged.

Several chancres are occasionally seen on the same individual if the infection occurs at one time, and it is possible that a patient may be infected at two different periods if only a short interval elapses between the inoculations; but the disease is not generally auto-inoculable, and when once a hard chancre has developed on the inner surface of the prepuce, the glans does not become infected from contact. Multiple chancres are always of small size, and the induration is less marked than usual.


FIG. 45.—PRIMARY CHANCRE OF THE LOWER LIP, WITH ENLARGEMENT OF SUBMAXILLARY AND SUBMENTAL GLANDS.

A **Urethral Chancre** is usually situated just within the lips of the meatus, constituting a sore with an indurated base. It may be felt as a hard nodule on grasping the urethra between the fingers, and gives rise to a thin serous discharge, often blood-stained. The orifice itself is sometimes the site of a hard chancre, which may encircle it, and be followed by a stricture.

Extragenital Chancres are most commonly observed on the lip (Fig. 45), finger, or nipple. They are often characterized by much infiltration, due to pyogenic inflammation, and less distinct and definite induration than in the forms met with on the genital organs; hence the swelling is more prominent and vascular, and if ulceration occurs there is a greater amount of discharge, which forms a thick scab over the surface. Neighbouring lymph-nodes are often much enlarged, and surrounded by infiltrated tissue. This condition has been mistaken for epithelioma, from which, however, it can be distinguished by the induration and sharp limitation of the sore, its rapid development, and the earlier enlargement of the glands. The course of the case is sometimes more severe than when the primary lesion is in the usual situation, a fact possibly explained by the disease remaining unrecognized till secondary symptoms develop. Digital chancres (Fig. 46) are usually seen in nurses, surgeons, and accoucheurs, and often start by the side of the nail. An indolent sore appears, which becomes infiltrated and ulcerates, spreading under the matrix and along the semilunar fold. There is considerable discharge and pain, and the terminal phalanx becomes

swollen and bulbous. The supratrochlear and axillary lymph-nodes are enlarged as the case progresses. Occasionally, however, the sore has been so small and so little obvious as to be overlooked.

Phagedena, or spreading gangrenous ulceration, is rarely seen at the present time, except as a complication of venereal disease, and seldom apart from syphilis. It attacks unhealthy and debilitated individuals, and is due mainly to the retention of discharges resulting from phimosis. The prepuce and end of the organ become red, swollen, and infiltrated. On dividing or retracting the foreskin, the affected surface is found to be sloughy, and the ulceration, unless checked by treatment, rapidly spreads, and may destroy glans and prepuce, and even attack the body of the penis. **Treatment** consists in division of the foreskin if that structure has not already been destroyed, followed by repeated immersion of the patient in a hot hip-bath. After the sloughs have been removed the wound should be dusted with iodoform and dressed with lint soaked in lotio nigra or eusol. The latter treatment is conducted as for primary syphilis, although the depressed condition of the general health may necessitate the administration of tonics, etc. Should treatment by immersion in hot water be for any reason impracticable, the cautery may be applied to the surface of the wound. Where there is much sloughing, this latter method may advantageously precede immersion in a bath.

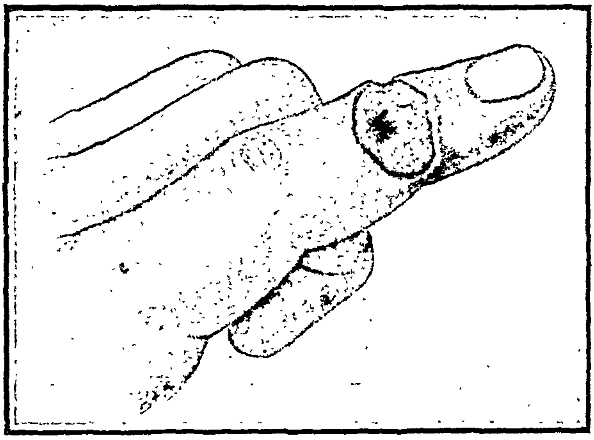


FIG. 46.—CHANCRE OF FINGER.

The **Lymph-Nodes** which receive lymph from the region in which the primary sore is situated become characteristically enlarged. They are freely movable under the skin and are hard like bullets, nodules of cartilage, or almonds (hence the term 'amygdaloid,' which has been applied to them); they are usually painless, and do not suppurate unless the original sore is infected also with the organism of soft chancre or with pyococci.

Occasionally the lymphatic vessels extending from the sore to the nodes become the seat of a chronic lymphangitis, and may be felt as hard cords beneath the skin. The dorsal lymphatic of the penis is frequently blocked in this way, and gives rise to solid or lymphatic œdema of the prepuce and glans. Should the chancre suppurate, abscesses may also form in the course of the lymphatics.

The **Duration** of the primary sore varies in different cases, and depends in great measure on whether treatment is commenced early or late. If the patient comes under observation during the first

six weeks, and appropriate treatment is at once started, the chancre usually heals over, the induration disappearing in from two to three weeks. The lymph-nodes in the groin, however, remain enlarged for some time. The longer the case is left untreated, the more slowly does the induration disappear, and, apart from treatment, may last for twelve months or more, and then gradually pass off, although it may run a much shorter course. From an uncomplicated syphilitic sore but little scar results, although a well-marked cicatrix may follow a soft or suppurating chancre.

Re-induration of the cicatrix (**relapsing chancre**) sometimes occurs from too early a cessation of antisyphilitic treatment, or from some localized irritation, or from a fresh exposure to infection. It is occasionally due to a tertiary or gummatous development, and will then be free from lymphatic complications.

II. **Secondary Syphilis.**—In the secondary stage, the spirochætes have become diffused generally throughout the body by means of the blood, which is itself infective. A certain amount of constitutional disturbance may exist, the patient feeling out of sorts, whilst in some cases distinct pyrexia, wasting, and headache may be noted. Secondary anæmia, particularly hæmoglobanæmia, well-marked, and sometimes severe, often supervenes, and a moderate lymphocytosis, absolute or relative, is present. The chief secondary manifestations consist in a general enlargement of the lymph-nodes, together with the appearance of various forms of rash on the skin and mucous membranes, loss of hair, and other less common phenomena, involving the eyes, brain, etc.; these usually show themselves in from six to nine weeks from the time of inoculation, although they may be delayed to a much later date. Their intensity varies considerably, the phenomena being in some cases scarcely evident, and in others marked. They are greatly influenced by the period at which treatment commences; the earlier it begins, the less obvious are the secondary symptoms.

The **Cutaneous Eruptions** of secondary syphilis are characterized chiefly by the fact that, although almost any form of rash may be simulated, no specially distinctive variety is originated. Moreover, in the same individual the eruption is not always of the same character throughout, several distinct types developing in different parts of the body (polymorphism). The rashes are usually more or less symmetrical (Plate IV.), the colour in the early stages being a dusky red, resembling that of raw ham; occasionally, however, they may be a bright rosy red. Syphilitic rashes usually give rise to but little irritation or itching. They tend to disappear after a time, often leaving a coppery-brown discoloration of the skin for a while; they do not completely fade on pressure, but leave a similar brownish-yellow discoloration.

The simplest form consists of a mere hyperæmia, sometimes appearing as a dusky mottling of the skin (*roseolous syphilide*), which quickly fades, or may persist whilst other types are developing. Sometimes distinct papillæ become infiltrated and hyperæmic (papular syphilide); at others, vesicles or pustules appear (*vesicular or pustular syphilide*); the latter change is uncommon, and appears only in bad cases or in

PLATE IV

Cutaneous Eruption in Secondary Syphilis

debilitated patients. Another form of eruption is the *squamous syphilide*, characterized by patches of hyperæmia and infiltration, combined with superficial desquamation. It is usually bilateral, and, unlike simple psoriasis, affects the flexor rather than the extensor surfaces. In the later stages, distinct nodules are produced in the skin, which may undergo ulceration (*'lupoid' syphilide*).

As to the situation of the rash, the roseola is usually limited to the trunk, whilst the other forms are often scattered widely over the trunk and extremities, involving, however, as noted above in the case of the squamous syphilide, the flexor more than the extensor surfaces of the limbs. A somewhat characteristic phenomenon is the appearance of a papular rash on the forehead, sometimes known as the 'corona veneris.'

The **Mucous Membranes** may be affected in much the same way as the skin. The fauces become red and congested, the hyperæmic area being abruptly limited and semicircular in outline; symmetrical ulceration usually follows, starting near the anterior pillars of the fauces, and spreading to the tonsils and along the soft palate to the uvula. These ulcers are shallow, have sharply-cut edges, and often present a characteristic greyish appearance, constituting what is known as a *'snail-track' ulcer*. The secondary sore throat rarely results in extensive loss of substance, and hence pharyngeal stenosis is not produced. Concurrently with these manifestations in the fauces bare patches from loss of epithelium may be seen on the dorsum of the tongue, or several small superficial ulcers may develop on the inside of the cheeks or lips, or along the borders of the tongue, from the irritation of the teeth.

Mucous patches and condylomata are somewhat similar lesions, though more pronounced, arising in the secondary stage in connection with mucous membranes and those parts of the skin which are soft and moist. **Mucous patches** consist of slightly-raised areas of enlarged and infiltrated papillæ, white in appearance, and often progressing to ulceration. Examined microscopically, the papillæ are found to be definitely enlarged, and the epithelium heaped up over them. They are most commonly observed at the corners of the mouth, on the inner aspect of the cheeks, the side of the tongue, or the margins of the anus; in the last-named situation they are usually symmetrical, one side being infected from the other. They are also not uncommon between the toes, and the ulcers caused thereby become exceedingly offensive. **Condylomata** are similarly the result of more marked overgrowth of the papillæ, differing from mucous patches merely in degree. They consist of wart-like masses, which may attain a great size, constituting a cauliflower-like growth. They are seen most commonly about the anus or vulva, in the former situation being often mistaken by the patient for piles; they give rise to an abundant, highly infective discharge. A similar condition sometimes occurs on the dorsum of the tongue, known as 'Hutchinson's wart.'

The **Lymph-nodes** are usually enlarged throughout the body during this period of the disease, being felt as round, hard swellings beneath the skin. The extent of the lymphatic complications is possibly a measure of the degree of virulence of the affection. Chronic enlarge-

ment, particularly of the nuchal and supratrochlear lymph-nodes, in the absence of any obvious local cause, is always suggestive of the possible existence of syphilis.

Syphilitic Alopecia.—The hair becomes dull and lustreless, and either comes out in patches from the scalp, eyebrows, etc., or there is a general 'thinning.' The follicles, however, are not destroyed, and the hair may subsequently regrow.

Syphilitic Iritis is characterized by pain in the eye, generally referred to the supra-orbital nerve, together with some interference with vision, and possibly a little lachrymation and photophobia. On examination a bright-red circular zone is seen immediately around the cornea, resulting from hyperæmia of the ciliary vessels. The iris is lustreless, and its definition somewhat blurred. Its colour is changed, a blue iris becoming greenish-yellow from the presence of lymph. The pupil is diminished in size, and perhaps irregular; its movements are always considerably hampered, and sometimes entirely prevented, by the formation of adhesions either to the back of the cornea (anterior synechiæ) or to the lens-capsule (posterior synechiæ). Occasionally small yellowish nodules are seen on its surface, consisting of plastic lymph.

The **Duration** and character of the secondary stage vary considerably. As already emphasized, the sooner effective treatment is commenced, the less severe the secondary phenomena. Hence the disease is often of an aggravated type when following undiagnosed extragenital chancres, as also in women, by whom the primary lesion often passes unnoticed. When treatment is commenced within four or five weeks of infection, the secondary stage may be slight, and all traces of its existence may pass off in two months or less; if treatment is delayed until the cutaneous eruption has appeared, this stage is likely to last longer. If the patient's general health has already been undermined, *e.g.* by alcoholism, etc., the syphilitic infection will follow a more aggravated course. Patients suffering from the debility caused by malaria or other tropical affections are particularly bad subjects, and the disease may then run a virulent course. **Relapses** during the first twelve months are usually due to intermissions in or inadequacy of the treatment. The rash which appears under these circumstances is often of a more characteristic type, the papules being grouped into rounded or confluent figures.

In the **Later Secondary Period** lesions appear which are not strictly gummatous, although they develop some time after the more acute manifestations of this stage of the disease have disappeared. These later secondary manifestations include flying pains (*osteoscopic*) in the bones, iritis, and various nervous lesions, whilst **periosteal nodes** may form on the tibiæ and other bones, or a symmetrical chronic effusion develop within the synovial membranes of joints. Some of the secondary manifestations, especially those of the bones and joints, may persist through this period, whilst even if they have disappeared the patient is liable to suffer from 'reminders' in the shape of various cutaneous affections. A bilateral epididymitis also is not uncommon, and is remarkable in that it is painful. The blood-vessels are not infrequently affected in this and later stages of the disease (*end-*

arteritis obliterans), the endothelium of the tunica intima undergoing proliferation; the lumen is thereby diminished, and the nutrition of the part supplied may be lowered, especially if thrombosis supervenes. Athero-sclerosis of the larger trunks may be induced by an affection of this type involving the vasa vasorum, and many forms of nervous disease may be lighted up if the cerebral or spinal vessels, either large or small, are involved. Paralysis of a single limb (monoplegia) may result, or of one side of the body (hemiplegia); but the affection may be limited to a single cranial nerve, or result merely in severe headache. Deep ocular lesions, *e.g.* choroido-retinitis, are also not unusual. The principal cutaneous affection is a squamous syphilide which may simulate psoriasis in appearance, and is most frequently seen on the palms and soles. An earlier squamous syphilide is often observed in the secondary stage, but is then symmetrical and readily influenced by treatment. In this intermediate period the lesion may be bilateral or limited to one side, according to whether it appears early or late. In the former there is a considerable tendency to proliferation of the epithelium, together with deep cracks and fissures; in the latter there is less epithelial overgrowth, but the edges are often distinctly serpiginous in outline, and there is an infiltrated border.

Rupia and **Ecthyma** are both met with in this stage of the disease, but only in patients whose nutrition is defective and when treatment has been neglected. They are characterized by an infiltration of the skin (in reality gummatous), which progresses to ulceration. In rupia the discharge forms a distinct scab on the surface, which increases in thickness by the deposit of successive layers, one under the other, each being somewhat larger than the one which precedes it; hence a scab shaped like a limpet-shell is produced, resting on an inflamed and hyperæmic base; any part of the body-surface may be affected in this way. In ecthyma no scab forms over the ulcerated surface, or, if formed, it readily comes away, leaving exposed a hollow punched-out sore, surrounded by an area of vivid congestion. Under appropriate treatment these conditions disappear, but leave depressed, whitish, rounded and nummular cicatrices, often surrounded by brownish pigmentation.

A somewhat unusual intermediate manifestation is a subacute symmetrical epididymitis, in which the cord also becomes thickened, enlarged, and tender.

III. **Tertiary Syphilis.**—The phenomena occurring in this stage may appear within six months of infection, or not for twenty or thirty years. They are mainly characterized by infiltration and overgrowth of the connective tissues of the body. This may occur in one or many places, and may be diffuse or localized. When diffuse, the organ or part affected becomes enlarged and hard, and, unless the condition is treated promptly, remains permanently sclerosed from the development of fibro-cicatricial tissue. If, however, the process is localized, a **Gumma** is formed.

Any tissue in the body may be the seat of a gummatous deposit, which apparently may arise without any ascertainable predisposing

cause, although occasionally its onset may be determined by an injury. The involved area becomes infiltrated with large oval endothelioid cells and small round lymphocyte-like cells; plasma-cells are usually present in considerable numbers. The constituents of this mass are similar to those which are found in a tubercle, but without the grouping into small nodules and the tendency to arrangement in zones; giant-cells may be absent, though their presence is by no means rare, and they may simulate, but are usually smaller than, those of tuberculous type. Very few vessels penetrate into the mass thus formed, which otherwise resembles granulation tissue; it gradually increases in size, infiltrating and replacing the normal tissues of the part. The fate of the fully-formed gumma varies according to circumstances. If the infection is a mild one, and especially if appropriate treatment is adopted, most of the cells become absorbed, and the remainder organized into fibrous tissue; even a large gumma may almost entirely disappear, leaving only a small fibrous scar.

FIG. 47.—ULCERATING GUMMATA OVER CHRONIC FIBROID DISEASE OF PATELLAR BURSA.

In the absence of proper treatment, most gummata undergo a necrotic change, which commences at the centre of the nodule and spreads towards the periphery. This may be a comparatively slow process, accompanied by fatty degeneration and caseation somewhat similar to that seen in tubercle; or it may be more rapid, the tissues undergoing a kind of mucoid degeneration, forming a gummy mass from which the lesion acquires its name. Sections through such a gumma will show a large white or slightly yellowish structureless centre of necrotic non-vascular material, surrounded by a zone of cellular tissue, which gradually merges into the normal structure of the part. Two factors are concerned in the production of this necrosis, *viz.* (*a*) the toxins produced by the causal organisms, and (*b*) the deficient blood-supply of the central portions of the cellular mass resulting partly from syphilitic endarteritis and in part from the associated peri-gummatous fibrosis almost invariably present.

Under appropriate treatment the whole of the gummatous mass may be absorbed, even when caseation or necrosis has taken place, but not infrequently the gummy, semi-purulent fluid which is formed at the centre of the mass finds its way to the surface and is discharged (Fig. 47). Where the necrotic mass is large, a portion of it may remain adherent to the surrounding tissues after ulceration has taken place, looking somewhat like a piece of wet chamois leather. Occasionally the central slough may become encapsulated by the formation of a layer of fibrous tissue around it, and calcification may supervene; this is most frequently found in the brain, testis, and liver. Malignant disease may in rare cases be superadded.

The appearances of surface gummata vary according to whether they are cutaneous or subcutaneous.

Cutaneous gummata are of frequent occurrence in tertiary syphilis, especially in the earlier stages. They appear as rounded dusky red nodules of firm consistency, and but slightly painful, and if they break down give rise to typical circular ulcers (Fig. 48). Many such nodules are often grouped together in one region, and when ulceration has occurred they produce by their confluence a sore with a *serpiginous* outline. Considerable destruction of tissue follows, but these sores are readily cured, giving rise to depressed white cicatrices which are supple and smooth and surrounded by pigmentation. Any part of the body-surface may be involved, but a common site is about or just below the knee on the outer, rather than the inner, aspect of the leg.

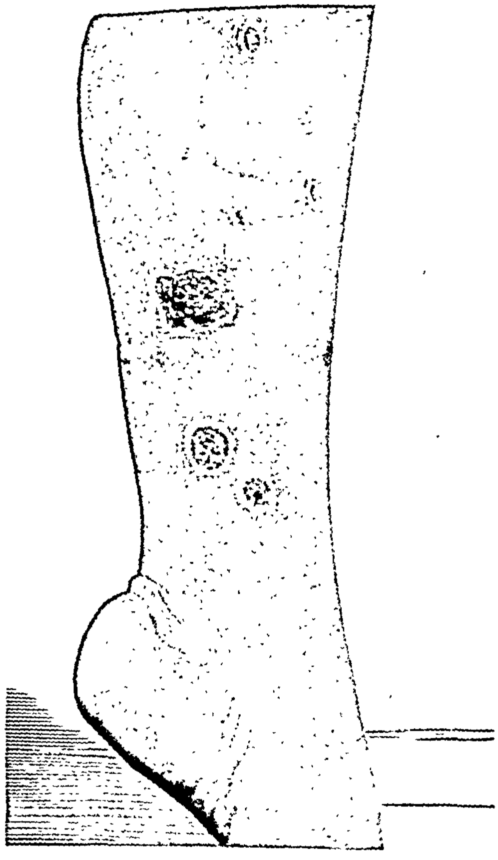


Fig. 48.—Cutaneous Gummata of Leg and Pigmented Scars.

Occasionally a diffuse infiltration of the skin is seen at this stage, appearing as a red hyperæmic area with a rounded or serpiginous border, and not at all unlike lupus in appearance (Fig. 49). It spreads rapidly at the margin, which is distinctly thickened, and may contain scattered nodules undergoing ulceration. Whether ulceration occurs or not, a cicatrix is produced. It is readily amenable to treatment, and runs a much more rapid course than lupus; the apple-jelly-like granulations so typical of the latter disease are of course not present.

A **subcutaneous gumma** develops as a firm nodule or an indefinite thickening, which gradually increases in size by the infiltration of surrounding tissues, and sooner or later approaches the surface; the centre of the mass in time becomes elastic and fluctuant; a certain amount of pain and tenderness is noticed, and when the skin is affected it becomes dusky, and even œdematous. If ulceration follows, the contents of the gumma escape, and the sore produced is circular and deep, the edges being sharply cut and perhaps undermined (Fig. 47); the base of the ulcer consists of granulation tissue, although it is sometimes covered by the characteristic slough. When these ulcers occur on the legs they are often mistaken for varicose ulcers, although their clinical characteristics should provide against this error.

More rarely a **diffuse gummatous infiltration** takes place, and is

seen most commonly in bone, the synovia, the meninges, the testis, and the muscles. The process will be described more fully in connection with the diseases of these organs.

Late tertiary (quaternary) manifestations also appear but are mainly medical in character, being confined to the cardio-vascular and the central nervous systems, and are the concern of the physician rather than the surgeon.

The **Prognosis** of syphilis has become much more favourable of recent years owing to two factors: (*a*) The possibility of demonstrating the presence of the spirochæte in the primary sore, before any typical induration has occurred, has placed in our hands a means of early diagnosis; and (*b*) the employment of salvarsan or its substitutes and other efficient antisyphilitic remedies suitably administered enable us to destroy all the spirochætes accessible to their influence.

The possibility of the complete and permanent cure of syphilis may be regarded as *now definitely established.* A marked feature

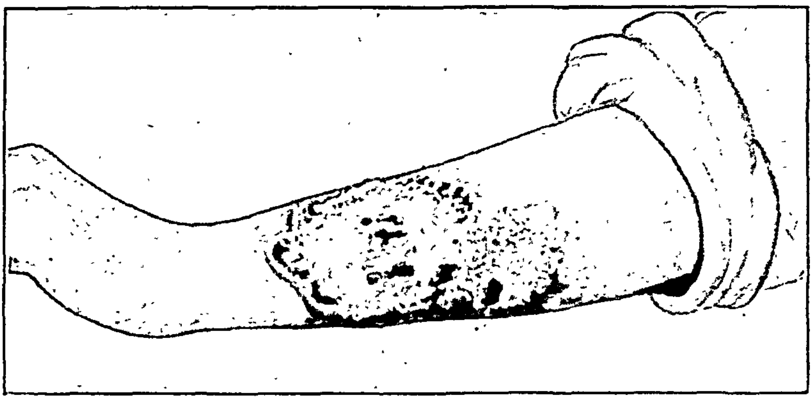


FIG. 49.—DIFFUSE GUMMATOUS SORE OF FOREARM.

of modern venereal work is the number of patients coming up for the treatment of hard chancres who have already been treated previously for syphilis. This certainly suggests that modern treatment places patients in a condition in which they again become susceptible to the disease on exposure, an occurrence of extreme rarity in the old days.

Whether or not a syphilitic patient will remain free from the later tertiary affections of blood-vessels (aneurisms, etc.) and of the nervous system (tabes, general paresis or paralysis of the insane, etc.) depends on the following four factors:

1. Early diagnosis.
2. Early and sufficient treatment by the combined use of salvarsan* and mercury, bismuth, etc.
3. Prolonged treatment with mercury, bismuth, etc., after the salvarsan course or courses are completed.
4. Return from time to time for the investigation of the Wasser-

* The term 'salvarsan' is used here to include the original '606' and its various recognized and efficient modifications.

mann and other serological reactions of the blood and cerebro-spinal fluid.

A patient who is seen early in the disease and who has been through a course of treatment with salvarsan and mercury should give a negative reaction early in the treatment, but this does not necessarily mean that he has been cured. After the termination of the treatment, his blood should be examined at intervals of three months and, as is often necessary and important, the condition of the cerebro-spinal fluid investigated. If there is no return of the reaction after a year, the probability is that he is cured; and if there is no return after two years, this is fairly certain; and at the end of three years may be regarded as practically conclusive. Patients who are not seen and treated until the later stages of the disease may never give a negative Wassermann reaction, however long and careful the treatment; such patients are probably incurable in the sense that they will always be liable to the development of fresh lesions if they intermit their treatment, but they are not likely to be infective to others, or now to transmit it to their children. A positive Wassermann reaction, therefore, in the later stages of the disease may, in thoroughly treated cases, perhaps be regarded as having a rather less prohibitive significance with regard to marriage than it has in the earlier stages (see also p. 164).

Some strains of the spirochæte appear to be more virulent than others, especially those acquired in the tropics, and some individuals are apparently more susceptible than others. Idiosyncrasies preventing the administration of salvarsan, mercury, bismuth, or iodide of potassium, militate strongly against a favourable prognosis, as does also the presence of any serious renal or hepatic disease. The state of health of the patient at the time of infection may influence the evolution of the disease, whilst the co-existence of tuberculous disease may render the outlook very unfavourable, especially when the syphilis is inherited.

Death is rarely produced by any of the secondary manifestations alone, except in the virulent forms developed in the tropics; but it is not uncommon in the tertiary stage, when important viscera, such as the brain, spinal cord, heart and vessels, liver, etc., are involved. In certain instances, the infection may be so virulent, especially if there has also been inadequacy or delay in treatment, that it may have to be regarded as practically incurable (**malignant syphilis**)—a condition most often seen in women.

Prophylaxis.—It is probable that syphilis can be prevented by washing the part exposed to infection with a solution of corrosive sublimate (1 : 1,000) or of permanganate of potash (1 : 1,000 or stronger), and rubbing in a calomel ointment (30 per cent.), if such treatment is undertaken within an hour or two of exposure. There is, however, the danger that, although the local occurrence of a chancre may be prevented, a general infection may have taken place.

The **Treatment** of syphilis has been transformed since the discovery by Ehrlich and Hata in 1909 of the substance known as **salvarsan** or 606, an organic arsenical preparation. It is a bright yellow powder slowly soluble in water and strongly acid in reaction. Its dose

is 0·3 to 0·5 gramme, given intravenously. **Neo-salvarsan** (N.A.B.) is an allied compound which is used more as it is less toxic and more soluble than salvarsan. Its dose varies from 0·45 to 0·9 gramme. There are numerous other preparations on the market, some of which may be given intramuscularly. As the solutions decompose after a certain interval, many of these preparations are put up in double ampoules (Fig. 50), the drug and its solvent being kept apart until immediately required for use. The patient must be carefully prepared as for operation, a purgative being given overnight, and no food permitted for three or four hours before and after the administration. He must stay in bed for twenty-four hours, or longer if pyrexia, muscular pains, headache, or other type of reaction supervene, and should take things quietly on the day after the dose.

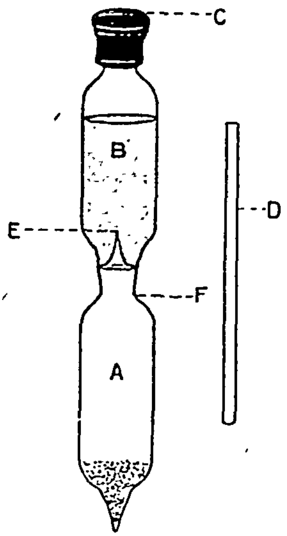


Fig. 50.—Double Ampoule for the Rapid Preparation of Fresh N.A.B. and Other Solutions.

It was at first believed that the effect of these drugs was to destroy all the spirochætes accessible to their influence, *i.e.* in the circulating blood or in the tissues; but it is now regarded as more probable that they act by stimulating the patient's tissues to do so. If the infection has been of long duration, and a certain number of spirochætes have become locked up in the walls of blood-vessels or in the nervous system, they may survive the salvarsan treatment, and consequently a complete sterilization of the system does not occur. It must be clearly remembered that salvarsan has not ousted mercury in the treatment of syphilis, but has diminished the amount of that drug required and shortened the period of infectivity.

Opinion differs as to the technique in treatment which is most effective. It is probably best to commence treatment with N.A.B., starting with 0·45 gramme once a week for three weeks. After an interval of one week two or three doses of 0·6 gramme at a weekly interval are given, followed by another week's rest. After this interval the dose would be raised to 0·75 gramme and given once a week for three more weeks. A course should include from seven to ten injections. At the same time this treatment should be supplemented by bismuth or mercurial medication. After the course of injections has been concluded the Wassermann reaction should again be tested.

The treatment to be chosen also depends on the stage of the disease. In an early case its aim should be to kill the spirochætes, and, for this purpose, treatment should be prompt, energetic, and thorough. In the later stages the problem is different. There is a chronic spirochætal infection which may never be cured, and vigorous treatment may give rise to considerable organic disturbance. In any case, treatment should be continued without intermission for at least

eighteen months. All cases should be kept carefully under observation for at least two or three years, and this must include the testing of the blood and c.s.f. for the Wassermann reaction, at first every month, and subsequently every three and then six months. A small provocative dose of N.A.B. should be given at the end of the first year after the cessation of treatment, and the serum reactions of blood and cerebro-spinal fluid tested, say a week later. The slightest sign of relapse, either clinically or by the Wassermann test, indicates the prescription of a further similar course of treatment. In tertiary syphilis salvarsan is useful in helping in the cure of active manifestations of the ulcerative type, but mercury and iodide of potassium still maintain their position, and must be employed. Over the deep lesions, especially of the neurosyphilitic parenchymatous type, salvarsan has but little influence.

Occasionally unfortunate results have followed the use of these powerful drugs, and a certain small percentage of mortality is liable to occur. Headache, fever and a rigor sometimes develop on the same day as the injection, passing off quickly; they are sometimes accompanied by vomiting and diarrhœa. Jaundice may be noted at a later date, usually not very intense, but occasionally severe and even fatal, being then due to acute or subacute hepatic necrosis (' yellow atrophy ' of the liver). Various forms of skin lesion may also occur, from a simple herpes to a severe dermatitis exfoliativa, which may be fatal. The percentage of these accidents is, however, decreasing steadily, and with increased experience and improving technique may be expected to fall still lower. They are due in part to the toxic character of the drugs, and possibly in part to the rapid destruction of spirochætes in the blood and tissues and the setting free of a large amount of endotoxin. The administration by the mouth of 1 to 2 ounces of glucose half an hour to two hours previous to the intravenous injection of the arsenical drug helps to protect the liver against its toxic action. The bowels should be thoroughly emptied, and only a light meal partaken of several hours previously. The urine should be examined regularly, especially for the presence of albumen and casts.

Bismuth is now extensively used, and is of especial benefit in cases which have proved resistant to arsenic and mercury. When administered alone, it causes fairly rapid disappearance of the lesions, but has a much slower effect on the Wassermann reaction. Some preparations are used in conjunction with arsenic salts, whilst others are used alone, consisting of precipitated metallic bismuth in isotonic salt solution. The injections are given every three or four days until a total of twelve to twenty doses has been administered, or until the Wassermann reaction is negative. The injections are intramuscular, the exact detail of dosage varying with each preparation. The complications to which it may give rise are stomatitis and albuminuria. Bismuth has not displaced either arsenic or mercury in the treatment of syphilis, but its administration may be additional to or alternate with either or both of these. It is also particularly useful in certain cases where mercury is not tolerated or is not effective.

The administration of **mercury** also plays an important part in the treatment of syphilis, but it must never be relied on alone unless salvarsan or one of its substitutes cannot be obtained, as even if a prolonged and thorough course of mercury is administered, the results are not satisfactory. Many different methods have been suggested in order that the patient may derive the greatest amount of benefit from the drug with the minimum of inconvenience. (*a*) It is often given **by the mouth,** and preferably in the form of pills, composed of grey powder (grs. i. to iii., *t.i.d.*), or of the green iodide (gr. ½ to i., *t.i.d.*). The grey powder may be combined with a little extract of opium or pulv. ipecac. co. if it causes diarrhœa; but this addition is not always needed. (*b*) **Inunction** of the mercurial ointment is also frequently adopted with success, inasmuch as it is less likely to cause digestive derangements. If the ordinary officinal ointment is employed, a portion as large as a hazel-nut is rubbed into the groin or axilla nightly, the part being washed the following morning, and not used again for this purpose for three or four days; if the ointment is made up with lanoline, a somewhat smaller amount is required. This is one of the best ways of bringing a patient rapidly under the influence of the drug. The course lasts six weeks, being repeated after six months. The **intramuscular** injection of mercurial preparations is now extensively employed, and increasing experience has proved it to be safe and efficacious in careful hands, and with due regard to asepsis. Insoluble preparations of mercury are mainly used, and especially in the form of metallic mercury suspended in a cream, *e.g.* Injectio Hydrargyri Intramuscularis '10 per cent.' according to Lambkin's original formula, or his Mercurial Cream made up with Palmitin, Creosote, and Camphoric Acid. The dose is injected deeply into the gluteal region, and the absorption, if slow, is regular, so that it is little likely to cause toxic symptoms. An injection should be carried out every five to seven days until some twenty to thirty have been given.

During the course of mercury, the patient's general health and habits must be carefully regulated; alcohol is forbidden, exercise limited, and strict instructions are given as to keeping the teeth and gums clean. An astringent mouth-wash containing alum or chlorate of potash should be ordered, and it may be necessary to remove or fill diseased teeth, but the dentist must, of course, be informed of the nature of the case. To minimize the risk of throat and mouth trouble, it is wise to stop smoking for at least six months. The dosage of mercury required varies in different individuals, being increased in robust people, and diminished in those who are weak or unhealthy. It should be pushed until mild effects are produced in the shape of slight tenderness of the gums, but 'salivation' of the patient is undesirable. Full doses are usually required for four or five months, followed by a milder course, which should extend at least till the end of the first year. It is advisable, however, to insist on a three months' course of mercury twice a year for two and a half or three years.

Symptoms of **mercurialism** are induced in some people by very small quantities of the drug, and hence treatment should always com-

mence with small doses. The gums become soft and spongy, and bleed readily on pressure; salivation follows, or even acute glossitis, whilst the breath becomes offensive. The teeth are loosened and may be shed, and the alveoli may undergo necrosis. Digestive derangements, such as colic and diarrhœa, are also observed. Treatment consists in suspending the drug for a time, and giving a sharp saline purge, whilst the spongy state of the gums is remedied by the use of alum or chlorate of potash mouth-wash already advised.

Iodide of potassium is essential in the treatment of the tertiary and intermediate stages. It appears probable that its chief action is the removal of gummatous tissue, probably by forming a soluble iodine albuminate, and that it has little influence upon the infection itself; in order to prevent recurrence, salvarsan or mercury is still required. The initial dose of iodide should not exceed 5 grains, and is gradually increased, until in some cases 1 drachm four times a day has been reached. Plenty of water should always be taken immediately afterwards to assist in its dilution and facilitate its absorption. A feeling of depression and sinking at the epigastrium is sometimes produced, but may be alleviated by the addition to the mixture of sal volatile (spiritus ammoniæ aromaticus ♏xv). Symptoms of coryza often follow, and an acneiform eruption over the shoulders and face, which may disappear on increasing the dose. Occasionally a vesicular, or even bullous, rash is caused by this drug. When large doses are given, bicarbonate of soda or potash must be combined with it, in order to prevent its decomposition by the gastric juice. If mercury is required, it is better to give it in the form of grey powder than to add liquor hydrargyri perchloridi to the iodide in a mixture. Other drugs, such as sarsaparilla, arsenic, and iron, are often combined with iodide of potassium in the later stages of the disease, and may be useful.

The **Local Treatment** of syphilitic sores consists mainly in the application of various preparations of mercury. The **primary chancre** may be treated by excision, cauterization, or the use of calomel ointment (30 per cent.), with the object of removing or destroying the spirochætes present in the fibrous interspaces. **Mucous tubercles** in the neighbourhood of the anus or vulva, or between the toes, are best dealt with by keeping them dry and clean, and dusting them over with powdered calomel and starch, or by the application of calomel ointment, a piece of lint being inserted between opposing surfaces to prevent them from rubbing one against the other. **Secondary ulceration of the throat** does not usually require local treatment, as it soon disappears under the influence of mercury. A mercurial gargle may, however, be employed, or in bad cases the affected parts should be painted with glycerinum hydrargyri perchloridi (1 in 2,000). **Superficial gummatous ulcers** are treated by removing the scabs, and applying some form of mercurial ointment. A determined attempt should be made to keep **deep gummatous ulcers** in an aseptic condition, since secondary septic infection of such sores, especially if they are connected with bone, makes a marked difference in their progress. In neglected cases they may become exceedingly foul, and in chronic cases a hectic

temperature and amyloid or waxy degeneration of the viscera may supervene. When gummata come to the surface and point, they should be opened with the same precautions as are adopted in the case of an abscess, and either dressed antiseptically or their cavity packed with sterile lint or gauze soaked in sterilized lotio nigra.

Inherited Syphilis.

Where the parents are syphilitic, pregnancy does not usually continue to full time, the mother miscarrying perhaps at the end of six or seven months. In these cases the child may be well formed, and may even live independently for a short while, but not unfrequently it is still-born, and in many cases macerated; in these circumstances the tissues are often teeming with spirochætes. Miscarriages may recur for several pregnancies, and then a living child be produced. If the infection occurs early in the pregnancy, the mother usually goes to full time, but her offspring is born with all the signs of congenital syphilis. If the disease occurs late in pregnancy, the fœtus may escape transplacental infection but become inoculated through a small abrasion acquired during the process of labour. In other instances, however, a living child may be born at full term at the end of the first pregnancy in spite of the syphilitic infection of the parents. This child may show evidences of the disease at birth, but more frequently appears to be healthy, specific manifestations not showing themselves for some weeks. The infectivity of the mother, and the degree of virulence of the disease in successive children, decrease with time, and it is possible that, after five or six years of untreated syphilis, a mother may bear a healthy and untainted child; although infection has been known to be transmitted much later.

As noted later (p. 167), the Wassermann reaction, however, may be negative in the infant's blood at birth, but may become positive some four or five weeks later. In this connection it is interesting to note that, although infective lesions may be present in the maternal passages, primary chancres are not seen in infants, who are presumably protected either by previous infection or by the presence of the vernix caseosa.

In some cases the mother has shown no obvious evidence of syphilis, and yet is able to suckle her child without harm, even though there are ulcerating lesions on the child's gums and lips, whereas a healthy wet-nurse develops a chancre of the nipple. This is known as Colles's Law, and was first stated by him in 1837. Investigation of the Wassermann reaction in these mothers has given a positive result in 90 per cent.; it is therefore practically certain that the apparent maternal immunity is in reality due to a previous mild and unrecognized infection.

The length of time during which a syphilitic patient of either sex retains the power of transmitting the disease to the fœtus is an exceedingly difficult point to determine, and one which is constantly coming before the practitioner, who is asked to decide at what period marriage is safe. The rule of practice generally followed is that no one suffering

from syphilis should be allowed to marry until the Wassermann reaction has remained negative and he or she has been free from all symptoms for two years, and even then it is advisable that a mild course of mercury should be given for about three months shortly before marriage.

In a few cases a positive reaction still persists in spite of such treatment, but in the absence of all clinical signs it is probable that the risk of marital infection would be slight; it would be wise, however, in the case of a subsequent pregnancy to put the mother under treatment.

The question of transmission to the third generation is one of much interest, concerning which a good deal of conflicting evidence has been forthcoming. The dependence of this disease upon a recognized

FIG. 51.—PROFILE OF BOY WITH INHERITED SYPHILIS, SHOWING DEPRESSED BRIDGE OF NOSE AND FRONTAL BOSSES.

FIG. 52.—CHILD WITH INHERITED SYPHILIS, SHOWING RADIATING SCARS ROUND THE MOUTH.

organism, which it has been possible to demonstrate in late tertiary stages, is presumptive evidence in favour of its transmissibility; but, naturally, one of the chief difficulties is the proof of absence of reinfection in the second generation.

Special Features.—The child may be born with many of the signs of congenital syphilis, of which the most common features are wasting, enlargement of the liver and spleen, jaundice, and a bulbous eruption on the hands and soles of the feet, which has been called *pemphigus neonatorum syphiliticus.* More frequently osteochondritis is present in 90 per cent. of cases, and the angles of the mouth may be fissured; however, the child appears well nourished and healthy for a variable period of from four to eight weeks. It then starts to waste, and a nasal catarrh, due to a *syphilitic rhinitis,* develops and impedes

respiration, producing the characteristic *snuffles.* There is a sero-purulent discharge and, in some cases, ulceration may take place and lead to necrosis of the bone, giving rise to a saddle-shaped depression at the root of the nose (Fig. 51).

Cutaneous lesions appear about the same time as the snuffles. The skin has a sallow, earthy hue. An erythema or eczematous condition appears about the nates and fissures occur about the lips and at the angles of the mouth which leave the characteristic radiating scars on healing (Fig. 52). At the same time condylomata may appear round about the anus. The hair of the head may fall out. As the disease progresses an anæmia develops, and the liver and spleen may become palpable.

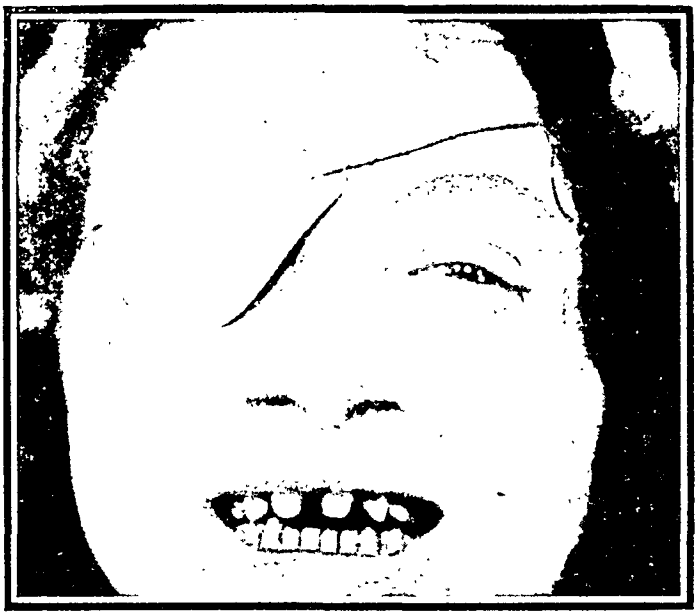


FIG. 53.—TEETH IN A CASE OF CONGENITAL SYPHILIS.
The girl also suffers from interstitial keratitis.

Many infants during the first year of life die from malnutrition or marasmus; but if properly treated a considerable proportion regain their health within six or eight months, all the manifestations described above disappearing, although their scars may remain. The child's subsequent development is frequently impaired, and it often retains an almost pathognomonic facies (Fig. 53).

After the first year, in untreated or in insufficiently treated cases, any of the tertiary phenomena which appear in acquired syphilis may develop, but, in addition to these, peculiar manifestations may be produced, affecting especially the teeth, bones, and cornea; deafness from disease of the internal ear is also not uncommon. The simultaneous occurrence of internal-ear deafness, interstitial keratitis, and deformity of the permanent incisors form the Hutchinson triad of congenital syphilis.

The **Teeth** in inherited syphilis are sometimes very characteristic. The temporary teeth usually appear early, are discoloured, and crumble away. The permanent teeth are often sound and healthy, but are sometimes deformed. The central incisors of the upper jaw are those most particularly affected, but the upper laterals and the incisors of the lower jaw may also be involved. Instead of being broader at the crown than at the root, they diminish in size from root to crown, being stunted, and separated from one another by interspaces. The angles of the crown are rounded off, and a distinct notch, forming a large segment of a small circle, occupies the centre (Figs. 53, 54). The enamel is often imperfectly developed, and hence they decay early. Occasionally they may be shaped like a screwdriver, narrowing from root to crown, and with a straight free edge. The notched and stunted teeth described above are sometimes known as 'Hutchinson's teeth,' but they are not now very commonly seen.

The **Bone** and **Joint** affections observed in inherited syphilis will be described in the chapter dealing with affections of bone and joints.

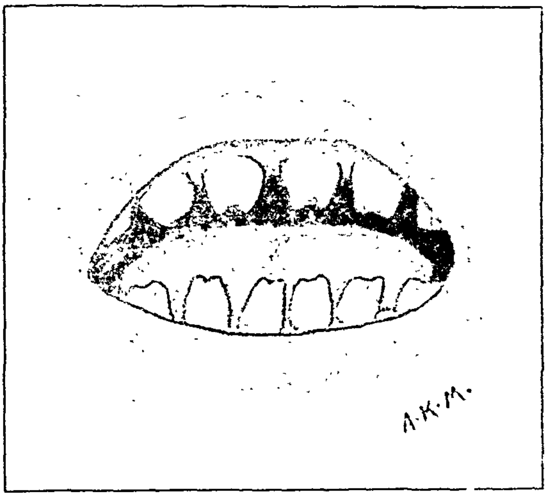


FIG. 54.—HUTCHINSON'S TEETH IN INHERITED SYPHILIS.

Interstitial Keratitis, or diffuse inflammation of the cornea, occurs usually about the age of puberty, or earlier. It is limited at first to one eye, but the other is almost certain to be similarly affected at a later date. It commences as a diffuse haziness of the cornea, which looks somewhat like ground glass, associated with hyperæmia of the ciliary region. Red areas, or 'salmon patches,' may be produced in the midst of the opacity, due to a new formation of minute vessels. There is no tendency to ulceration, but in protracted cases the anterior part of the eye may bulge forwards, constituting a condition known as 'anterior staphyloma.' The inflammation may spread to the iris and ciliary body. With suitable precautions the cases usually do well, although treatment for several years may be necessary, and some corneal opacity may persist. Infection of the middle ear via the Eustachian tube occurs as a result of rhinitis and may lead to necrosis of the ossicles, or that of the internal ear may lead to deafness, especially about the age of puberty.

The Wassermann reaction in congenital syphilis is usually positive in the earlier, more active stages. In some cases, however, in which the child appears healthy at birth, the reaction may be negative but may become positive a month or more after birth (*cf.* p. 164). As the child grows, and especially about puberty and in adolescence, it

may be diminished or absent, as in the later tertiary stage of the acquired variety.

Where the presence of such infection has not been suspected, the **Treatment** of inherited syphilis should commence as soon as definite manifestations of the disease are present. When either of the parents is known to be syphilitic, treatment must be carried out during antenatal life through the mother. The general health must be attended to, and if the mother is unable to nurse the child it must be 'put on the bottle'; on no account must it be given to a wet-nurse. Minute doses of arsenical preparations of the '914' type are given at first into the great longitudinal (sagittal) venous sinus, through the anterior fontanelle. The intramuscular route is probably easier than the intravenous, but the latter is desirable for the first few doses. Sulpharsenol is well tolerated by babies. When the gross lesions have disappeared, mercury must be employed, and is best administered by anointing the under surface of an abdominal binder with mercurial ointment, or the same preparation may be rubbed into the soles of the feet every night. This should be continued until all secondary phenomena have disappeared, and in any case until the child is two years old. It is sometimes wise to replace this by the internal administration of grey powder, ½ or 1 grain thrice daily, with a little sugar. Cod-liver oil or one of its substitutes, such as haliverol, may also be ordered with advantage in some cases, and every possible means adopted to improve the general nutrition by suitable dieting and the administration of vitamins, etc. When tertiary symptoms appear, iodide of potassium and mercury should be given in suitable doses.

The local treatment of external lesions is conducted according to the rules laid down for the acquired type of the disease.

Tuberculosis.

Tuberculosis is an infective disease, the causal organism of which is the tubercle bacillus, the name being derived from the characteristic nodules or 'tubercles' usually present in the tissues.

Predisposing Factors.—The direct transmission of the infection from the mother to the child *in utero* is probably very rare, the fact that there are families in which tuberculosis is specially prone to occur being due rather to the combination of circumstances facilitating the direct infection after birth of the children of tuberculous parents. Although tuberculous disease is most frequently seen in children or young people, no age is exempt from its attacks, even elderly people being affected. The senile manifestations differ in no way from those met with in the young.

A depressed condition of the general health is a very important predisposing cause of tuberculosis. Thus not infrequently the disease starts in children after attacks of the exanthematous fevers, or as a sequel of rickets, or other childish ailments. Many of these leave an inflamed condition of the pharynx or intestine, and thus provide a suitable entrance for the bacillus. In adults, also, the debilitating

PLATE V.

Fig. 1.—*Treponema pallidum* (Spirochæta pallida) in Scraping from Hard Chancre, shown under Dark-ground Illumination, along with several Red Blood-corpuscles and some Staphylococci. (×1000.)

Fig. 2.—*Treponema pallidum* (Spirochæta pallida) in Section of Liver from Case of Congenital Syphilis.

(Stained by Levaditi's Silver Impregnation Method, ×1000.)

Fig. 3.—Tubercle Bacilli in Film of Sputum from Case of Chronic Phthisis.

The acid-proof tubercle bacilli are stained red, other organisms of secondary infection blue. (Ziehl-Neelsen Method, ×1000.)

Fig. 4.—Tuberculosis of Synovial Membrane of Knee-joint.

Section showing part of a 'giant-cell system,' showing central giant-cell, endothelioid, and small lymphocyte-like cells, and tubercle bacilli. (Ziehl-Neelsen Method, ×500.)

Fig. 5.—Tubercle Bacilli in Film of Centrifugalized Deposit of Cerebro-spinal Fluid from Case of Acute Tuberculous Meningitis.

Small lymphocyte-like cells, polymorphs and an endothelial cell are shown. (Ziehl-Neelsen Method, ×1000.)

Fig. 6.—Leprosy Bacilli, mostly within the 'Lepra-cells,' in a Section of Subcutaneous Leprous Granulation-tissue.

These cells are analogous to the 'endothelioid cells' of tuberculosis. (Modified Ziehl-Neelsen Method, ×1000.)

Fig. 7.—*Actinomyces bovis* in Section of Human Liver-abscess, showing Branching Gram-positive Filaments at Periphery of Colony radiating out among Pus-cells: Bacillary and Coccoid Forms, and Amorphous Centre.

(Gram's Stain, ×500.)

Fig. 8.—*Actinomyces bovis* in Section of 'Woody Tongue' of Cow, showing Two Colonies with 'Clubbing' of the Sheaths of the Filaments at the Periphery, Central Degeneration with Commencing Calcification, and Surrounding Granulation-tissue with Endothelioid Cells and Polymorphs.

(Gram's Stain, ×300.)

PLATE V.

FIG. 1.—*Treponema pallidum* (SPIROCHÆTA PALLIDA) IN SCRAPING FROM HARD CHANCRE, SHOWN UNDER DARK-GROUND ILLUMINATION, ALONG WITH SEVERAL RED BLOOD-CORPUSCLES AND SOME STAPHYLOCOCCI.

(×1000.)

FIG. 2.—*Treponema pallidum* (SPIROCHÆTA PALLIDA) IN SECTION OF LIVER FROM CASE OF CONGENITAL SYPHILIS.

(Stained by Levaditi's Silver Impregnation Method, ×1000.)

FIG. 3.—TUBERCLE BACILLI IN FILM OF SPUTUM FROM CASE OF CHRONIC PHTHISIS.

Acid-proof tubercle bacilli are stained red, other organisms of secondary infection blue. (Ziehl-Neelsen Method, ×1000.)

FIG. 4.—TUBERCULOSIS OF SYNOVIAL MEMBRANE OF KNEE-JOINT.

Section showing part of a 'giant-cell system,' showing central giant-cell, endothelioid, and small lymphocyte-like cells, and tubercle bacilli. (Ziehl-Neelsen Method, ×500.)

FIG. 5.—TUBERCLE BACILLI IN FILM OF CENTRIFUGALIZED DEPOSIT OF CEREBRO-SPINAL FLUID FROM CASE OF ACUTE TUBERCULOUS MENINGITIS.

Small lymphocyte-like cells, polymorphs and an endothelial cell are shown. (Ziehl-Neelsen Method, ×1000.)

FIG. 6.—LEPROSY BACILLI, MOSTLY WITHIN THE 'LEPRA-CELLS,' IN A SECTION OF SUBCUTANEOUS LEPROUS GRANULATION-TISSUE.

These cells are analogous to the 'endothelioid cells' of tuberculosis. (Modified Ziehl-Neelsen Method, ×1000.)

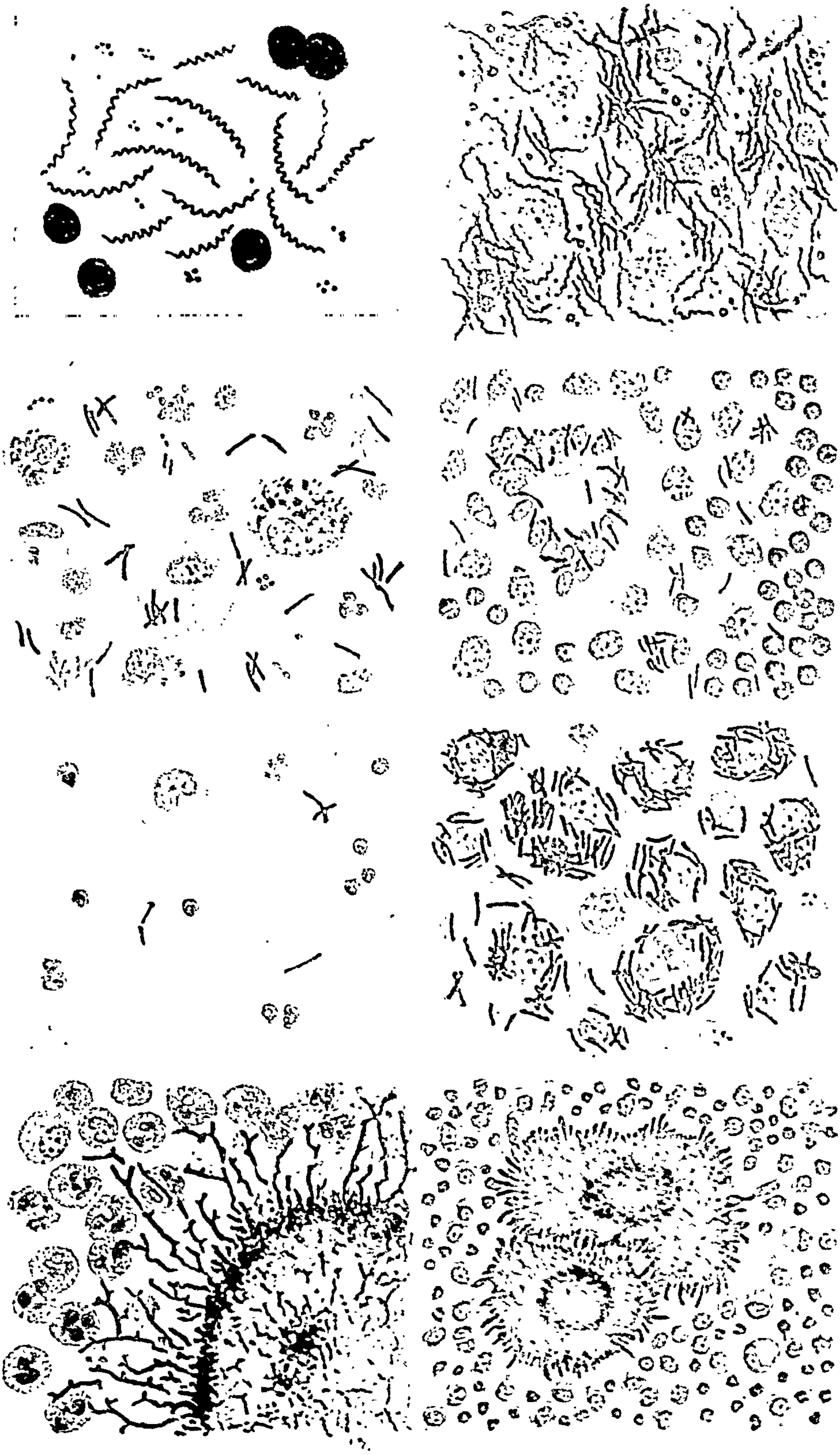
FIG. 7.—*Actinomyces bovis* IN SECTION OF HUMAN LIVER-ABSCESS, SHOWING BRANCHING GRAM-POSITIVE FILAMENTS AT PERIPHERY OF COLONY RADIATING OUT AMONG PUS-CELLS; BACILLARY AND COCCOID FORMS, AND AMORPHOUS CENTRE.

(Gram's Stain, ×500.)

FIG. 8.—*Actinomyces bovis* IN SECTION OF 'WOODY TONGUE' OF COW, SHOWING TWO COLONIES, WITH 'CLUBBING' OF THE SHEATHS OF THE FILAMENTS AT THE PERIPHERY, CENTRAL DEGENERATION WITH COMMENCING CALCIFICATION, AND SURROUNDING GRANULATION-TISSUE WITH ENDOTHELIOID CELLS AND POLYMORPHS.

(Gram's Stain, ×300.)

PLATE V



[To face page 168

effects of influenza, a neglected cold, or persistent overwork may be followed by the development of the disease.

Still more is this likely to happen if the patient lives in unhealthy or bad hygienic surroundings. Hot and ill-ventilated workrooms, dark, dirty and overcrowded dwelling-houses, etc., are themselves harmful by lowering vitality, but they often become hotbeds of infection if consumptive patients are admitted and contaminate the air by coughing and expectorating. This probably explains the terrible frequency with which tuberculosis occurs in many places where one would expect the inhabitants to be particularly healthy, *e.g.* some of the holiday resorts of Scotland, Wales, and Ireland; the houses are small, dark, often dirty, and so devoid of ventilation that, if one member of the household contracts tuberculosis, it often spreads rapidly to others. Naturally, tuberculosis is most common amongst the poor, but it is also still only too frequent in the well-to-do.

A pre-existing local nidus in the body suitable for the development of the micro-organism is usually present, although tuberculous infection very occasionally follows wounds and punctures in previously healthy parts. Thus, chronically inflamed lymph-nodes form a suitable breeding-ground for the bacillus, as also bones and joints in a state of congestion resulting from slight and often overlooked injuries.

The ultimate exciting cause of tuberculosis is the entrance and development within the tissues of the tubercle bacillus of Koch (Plate V., Figs. 3 and 5). It usually occurs in the form of slender rods, straight or slightly curved, about 4 or 5 μ in length and 0·2 or 0·3 μ in width, but sometimes forming filaments. The tubercle bacillus is a typical 'acid-fast' or, more correctly, 'acid-proof,' organism, and when stained by the Ziehl-Neelsen method appears in the form of slender red rods, which are often stained only in part, so that they seem to consist of short red alternating with unstained segments. *In vitro*, on suitable culture-media, they develop very slowly, two or three weeks elapsing before growth is visible, and require a temperature approaching that of the body and an abundant supply of oxygen. The colonies consist of yellowish-buff, white, or grey scales, which have a dryish look.

A distinction is now definitely established between the human and the bovine types of the tubercle bacillus, and the varieties of the disease produced by each. Both can develop in human beings, but the bovine type is mainly responsible for intestinal and surgical forms of the disease, *e.g.* those attacking lymph-nodes, bones, and joints, whilst the human variety leads usually to pulmonary phthisis and to acute general tuberculosis. Cultural distinctions are readily established. The results of inoculation experiments in rabbits also differ, in that the human type of tubercle bacillus produces but little effect and rarely kills, whereas the bovine type is actively fatal. Avian and piscine types of tubercle bacilli, attacking birds and fishes respectively, are of much less direct importance and but rarely affect man.

The organism gains access to the body in any of the following ways:

(*a*) **By inhalation.** The sputum of consumptives may contain vast

numbers of tubercle bacilli, and, as drying does not immediately kill them, living bacilli frequently occur in dust and in the air. It is also important to realize the fact that in coughing and even in talking the tuberculous sputum is expelled in a state of very fine division, and the infective particles remain suspended in the air for long periods. Tuberculosis acquired by inhalation manifests itself usually in the form of pulmonary disease, but may appear as an affection of the cervical, mediastinal, and bronchial lymph-nodes, from which the infection may be disseminated to other organs, including the lungs.

(*b*) **By ingestion,** *e.g.* of infected milk from cows with tuberculous disease of the udders. This is by no means rare, and, in some parts of the country, very common in children, the bacilli entering especially through the tonsils or other lymphadenoid tissues of the pharynx and invading the cervical glands, or passing through the stomach unharmed and infecting the intestine and mesenteric lymph-nodes. Examination of tuberculous material from the cervical glands in 72 cases in Edinburgh resulted in the discovery that in 65, *i.e.* 90 per cent., the bovine bacillus was present.

(*c*) **By inoculation.** This is very unusual, and occurs chiefly in pathologists, post-mortem room porters, butchers, etc., in the form of a wart-like tuberculide, known as verruca necrogenica, or post-mortem wart. A few cases of tuberculous infection from an accidental cut inflicted by a broken sputum-cup have been recorded.

The laboratory diagnosis of tuberculosis is conducted on one or more of the following lines:

1. By the microscopical identification of the tubercle bacillus after staining by the Ziehl-Neelsen method.

2. By growing the bacillus upon special media, the material for cultivation being, if necessary, as in the case of sputum, treated with alkali for the destruction of other contaminating organisms.

3. By the inoculation of susceptible animals, especially guinea-pigs. At least two animals should be inoculated from each case. The suspected material—whether exudate or tissue—is usually inserted beneath the skin of the groin, and one animal may be killed in, say, three weeks, when, if the test is positive, the lymph-nodes and probably the internal organs will be found tuberculous. A definitely negative result cannot, however, be assumed unless the other inoculated animal survives for at least six weeks, and is then, when killed and examined, found to be free from tuberculosis.

4. A characteristic of most tuberculous exudates is the presence of small lymphocytes or lymphocyte-like cells as the prevailing type.

5. In some cases a portion of the lesion may be excised and submitted to microscopical examination, which should also include a search for bacilli, since other infections may give rise to lesions histologically resembling those of tuberculosis.

6. Tuberculin (as originally prepared by Koch) is obtained by evaporating down a six-weeks-old glycerine-broth culture of the organism, killing it by heat, and filtering. The filtrate has been used as a diagnostic agent, but the method is not free from danger and is

therefore little used. A safer procedure is that known as **Von Pirquet's skin-reaction.** It consists in inoculating a small superficial scarification with a drop of tuberculin, pure or diluted 1 in 10. The positive reaction consists in the development in from twenty-four to forty-eight hours of a violet-red papule with a characteristic regular or festooned margin. This persists for five or six days, and then fades away. There is no accompanying fever. This test is of considerable value, especially in children up to twelve years of age. The intracutaneous injection of diluted tuberculin is, perhaps, a more delicate method. In the test proposed by Mendl and Mantoux, 0·1 c.c. of dilutions varying from 1 in 1,000, 1 in 10,000, etc., up to 1 in 1,000,000 Old Tuberculin are used. In most countries the percentage of positive reactions gradually increases with age.

7. Finally, complement-fixation tests are at present unreliable.

8. The sedimentation-rate of the red blood-corpuscles, though not a specific test for tuberculosis, is a valuable aid, particularly in regard to prognosis and the control of treatment. It is as a rule progressively accelerated in proportion to the severity of the tuberculous infection, and a return towards normal may usually be regarded as a favourable sign.

Pathological Anatomy.—The most characteristic lesion is the **miliary tubercle,** a cellular mass varying in size up to 2, or perhaps 3, millimetres in diameter. When young and cellular, tubercles are soft, translucent, and of a grey colour, tending later to become caseous, yellow, and opaque.

A typical fully-formed tubercle without retrogressive changes can best be studied in sections from the meninges in tuberculous meningitis, or from the liver or kidney in a case of general tuberculosis. In the centre of the mass there is usually a giant-cell (Fig. 55), which may be oval or circular or sometimes very irregular in shape, with many rounded or oval nuclei, which tend to be arranged round the periphery of the cell. Around the giant-cells there is a zone of endothelioid cells, usually somewhat oval in shape, and their nuclei resembling those of the giant-cell. Beyond this is a third or outer zone of small round inflammatory cells, usually regarded as identical with lymphocytes, together with a varying number of plasma-cells. All tubercles do not conform exactly to this typical description. The giant-cell, for example, is frequently missing, especially in acute cases, or there may be several cells of this type. Moreover, the width of the zones varies greatly; in some cases the endothelioid cells may not be in evidence, but can be detected among the lymphocytes, which may extend to the centre of the tubercle.

The changes which may take place in a fully-formed tubercle vary according to the virulence of the bacilli and the resisting powers of the patient:

1. When the bacilli are but slightly virulent and the patient's susceptibility moderate, the tubercle undergoes **fibrosis;** this is the natural method of cure.

2. When the bacilli are virulent and the patient in a non-resistant condition, **caseation** occurs. This is a necrotic process by which the

affected tissues are transformed into a uniform structureless mass staining only with acid dyes, such as eosin. Though acid-proof tubercle bacilli may often not be demonstrable microscopically in this material, it may be proved to be infective by the production of tuberculosis in animals inoculated with it.

Cure may take place at this stage by a process of fibrosis of the surrounding parts, so that the caseous mass becomes walled in by a zone of fibrous tissue, the cheesy material gradually dries up, and may become calcified. It is possible, however, that the living bacilli may persist in such dried-up caseous material, and, under suitable conditions, recrudescence may ensue, even after an interval of years.

FIG. 55.—EARLY TUBERCLE-FOLLICLE IN SYNOVIAL MEMBRANE.

A small multinucleated giant-cell, about a dozen endothelioid cells, and numerous small lymphocyte-like cells are shown. (× 300.)

3. In most cases in which caseation is present, the process continues to spread, and involves, not only the tubercles, but also the intervening tissues; in this way cheesy masses of considerable size may be produced. Not unfrequently an exudation of fluid takes place into this mass, and the result is a **chronic tuberculous abscess.** Such chronic abscesses may supervene in any affected tissue, but occur most frequently in bones, joints, and lymph-nodes.

The pus-like exudate from such an abscess consists of disintegrating caseous necrotic material mixed with a variable quantity of fluid, so that it is sometimes thin and milky, sometimes so thick that it will scarcely flow through a cannula. It often contains masses or flakes

of curdy débris, and on microscopical examination a few lymphocytes may be seen, together with much amorphous granular material. Tubercle bacilli may be numerous in the more active cases, but in chronic forms they are often very scanty, and their presence can be demonstrated only by inoculation experiments. In old-standing cases cholesterol crystals are present.

Secondary infection with pyogenic bacteria may supervene, and, although the exudate in such a case may not differ appreciably from the ordinary pus of an acute abscess, the fact that it contains tubercle bacilli may be demonstrated by inoculation.

The structure of a tuberculous abscess wall is characteristic. The cavity is lined by a layer of grey, yellowish-grey, or pinkish, pulpy tissue, containing miliary tubercles, perhaps undergoing caseation. Its colour and vitality are dependent upon the chronicity or otherwise of the process; the longer the abscess is in forming, the less vascular the membrane, owing to the associated sclerosis of the surrounding structures leading to obliteration of the blood-vessels, and to the accompanying chronic endarteritis. This lining membrane, when necrotic, is but loosely connected with a layer of fibro-cicatricial material, which forms the outer part of the wall, and from which it can be readily detached.

A chronic abscess forms a soft fluctuating swelling which gradually increases in size, and may become painful by exerting pressure on nerves or other sensitive structures. Should it be **superficial,** it will probably come directly to the surface and burst; the exudate and caseous detritus will be discharged, and possibly, if the general health is good, the wound may slowly granulate and heal; but not unfrequently the tuberculous tissue left behind prevents healing, and a **tuberculous ulcer** develops. A similar condition is found in connection with mucous membranes, the tuberculous foci starting in the submucosa, and subsequently bursting through the mucous membrane. Whatever their location, the ulcers are characterized by an irregular and ragged margin with undermined and congested edges (Fig. 56, C); the base is formed by pulpy granulation tissue containing caseous foci, which must be removed before healing can occur.

On the other hand, a **deep abscess** is likely to burrow along fascial planes, and may become superficial at a distance from its original source, *e.g.* in a psoas abscess due to tuberculous disease of the spine. The far-reaching extent of these abscesses, and the impossibility of dealing adequately with the lining membrane or with the original focus, render them difficult to treat, and fully account for the dread of opening them experienced by surgeons in pre-antiseptic days; for under the best of circumstances a **sinus** is liable to develop and persist, and without the most scrupulous precautions pyogenic infection is likely to ensue, followed by an increased discharge of tuberculous exudate, aggravation of the original disease, and only too frequently death from chronic toxæmia.

A tuberculous abscess, if left to itself, does not necessarily come to the surface. Occasionally one meets with a mass of putty-like consistency lying in front of the spine in the body of a patient

who has been cured of spinal disease. This is evidently the desiccated remains of a chronic abscess, the fluid portion having been absorbed, and the solid elements left behind, encapsuled and perhaps infiltrated with lime-salts. Similarly one kidney may occasionally be entirely destroyed by tuberculosis, and its calcified remains found post-mortem.

One of the chief dangers of tuberculous disease is its great tendency to diffusion, which may occur (*a*) locally, by direct continuity of tissue, *e.g.* along the walls of natural passages, as well as by their lumen and contents, *e.g.* from the epididymis by way of the vas deferens to the prostate and seminal vesicles, or by extension along neighbouring

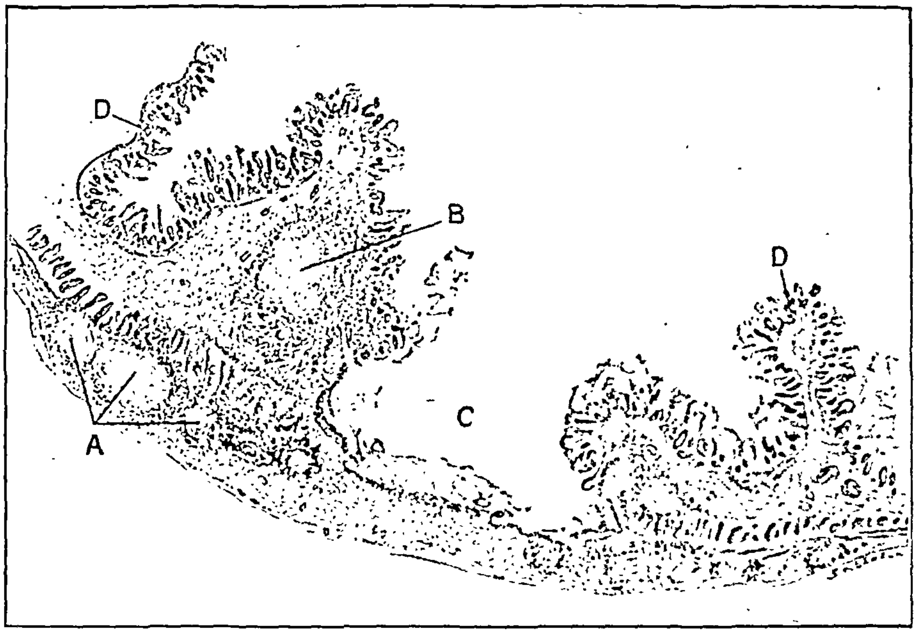


FIG. 56.—TUBERCULOUS ULCERATION OF ILEUM.

A, Subserous tubercles undergoing caseation; B, submucous tuberculous abscess; C, tuberculous ulcer; D, intestinal villi covered with surviving but catarrhal mucous membrane.

lymphatics or blood-vessels. (*b*) Distant organs or tissues may become infected, probably by embolic dissemination in the lymph- and blood-stream. Thus, phthisis is a not uncommon sequel of a similar affection of bones, joints, or lymph-nodes. The swallowing of infected sputum often leads to ulceration of the bowel and infection of the mesenteric lymph-nodes, etc. (*c*) Moreover, any tuberculous lesion may lead to acute general tuberculosis, in which the disease is widely diffused throughout the body, affecting practically any or every organ and serous membrane, including the meninges, and giving rise to rapid emaciation, high fever of an intermittent type, and usually severe diarrhœa, dyspnœa, and delirium or coma, death ensuing in a few weeks.

Treatment.—When Koch first discovered the tubercle bacillus, a great impetus was given to operative treatment, and some authorities went so far as to maintain that every particle of the diseased tissue must be extirpated with as much care as in the case of cancer. The pendulum has now swung slowly back, and we are relying more and more on the natural powers of repair inherent in the patient, and are endeavouring rather to maintain and increase these in every way by suitable general and local treatment.

1. **General Treatment** of the sanatorium type under suitable climatic conditions is indicated in all cases of tuberculous disease. Failing sanatorium treatment, much good may be effected by exposure to sunshine and air wherever available. Heliotherapy applied to the body generally, or locally to the affected part, is most valuable, or in the absence of sunshine exposure to ultra-violet rays, careful dosage being required until immunity from harmful effects has been secured. Indications of improvement are shown, not only by relief from local pain, but also by a more regular and normal temperature, increasing weight, improvement in the hæmoglobin content and sedimentation rate of the red corpuscles. Care must be taken to protect the patients from cold in winter, and they must be given an abundant and nutritious diet with suitable vitamin-content. Whilst the disease is still active, the amount of exercise must be strictly limited. The administration of haliverol, as well as various other vitamin-containing preparations and other tonics, is useful. Many forms of tuberculin have been introduced since the failure of Koch's original variety as a therapeutic agent. Opinions vary as to the value of this method of treatment, but in surgical cases where efficient sanatorium treatment is possible, its use is not indicated except when improvement does not otherwise occur. Under such circumstances, in a child, 0·00001 milligramme may be given hypodermically, increased gradually up to 0·001 milligramme, whilst an adult may start with a dose of 0·0001 or 0·0002 milligramme. The injections should not be repeated under ten or fourteen days, and should never be attempted when a mixed infection is present.

Preventive Vaccination with B.C.G. (Bacillus Calmette-Guérin) Vaccine.—Calmette, after a long series of trials, succeeded in growing a strain of bovine tubercle bacilli, which, by repeated cultivation upon a bile-containing medium, gradually became non-virulent, as tested by the inoculation of guinea-pigs. With these living but attenuated bacilli he, in 1921, ventured, apparently with success, to administer it orally to a human infant whose mother had died of tuberculosis and who was to be brought up by a tuberculous grandmother. Since this initial experiment, many thousands of infants, as well as considerable numbers of older persons, such as medical students and hospital nurses, who by their work are exposed and liable to infection, having been treated orally or by injection with B.C.G., appear to show that a definitely increased degree of immunity is conferred which, though not preventing infection, renders the disease distinctly less virulent, with a considerable reduction of both the morbidity and mortality figures.

Local Treatment (Non-operative).—Absolute rest of the affected part as far as is possible is the first principle of treatment. In the case of joints, complete immobilization may be effected by plaster of Paris splints and the effect of the weight of the body minimized by recumbency or other means when the disease affects the spine or lower extremities. When complete immobilization is not possible, partial rest is still of great value; thus the method of collapsing the lung by means of an artificial pneumothorax is of the greatest service in treating phthisis. Every precaution should be taken to prevent the occurrence of a mixed infection. A patient with glandular infection in the neck should be carefully treated for any peripheral septic lesions, *e.g.* of the lips, teeth and gums, the ear, nose, scalp, etc.; enlarged tonsils and adenoids should also be removed, inasmuch as bacteria are often lodged in them.

3. **Operative Treatment** is required when the measures indicated above have failed to check the disease, or when accidental complications, *e.g.* abscesses, develop in the course of the case, or when the disease is so extensive or progressive as to make it inadvisable to trust to natural processes of repair alone. Obviously, **extirpation** of the tuberculous focus, if practicable, is the ideal treatment in all cases, and for some conditions no other treatment need be considered. In superficial lymph-nodes in the neck excision is the best treatment whenever progress to recovery is delayed or absent. In many other conditions, as in bone and joint disease, total extirpation is practicable by excision or amputation; but such a proposal involves the consideration of many other questions, such as the operative risk, the possibility of a general diffusion of tuberculous material by the necessary manipulations, the possible infection of the wound or surrounding healthy tissues by tubercle, and the degree of post-operative disability that may result. The cure by a local excision is not always certain, and the after-treatment is often very prolonged. On the other hand, Nature's cure may be equally uncertain, possibly less satisfactory, and the chances of dissemination and diffusion are not absent. The final decision as to the advisability of undertaking a radical operation of this type must be made by a careful consideration of (1) the stage of the disease, whether early or late; (2) its position and extent locally; (3) the presence or otherwise of tuberculous disease elsewhere in the body; (4) its character, whether active and progressive, or chronic; (5) the probable resisting power of the patient to the spread of the disease and to the occurrence of amyloid degeneration of important organs and tissues, and of secondary infection; and (6) the hygienic conditions, etc., under which treatment has to be carried out.

Partial operations are sometimes required, consisting in cutting or scraping away as much of the diseased tissues as is practicable, swabbing out the cavity thus produced with some powerful germicide, such as liquefied carbolic acid, and dressing the part with gauze soaked in some antiseptic substance, such as an emulsion of iodoform, the wound being left to heal by granulation. Diseased bones, lymph-nodes, and sinuses have sometimes to be dealt with in this way, and

satisfactory cures may in time result. Open-air treatment must be instituted at the same time, or commenced as soon after as possible.

When the patient suffers from more than one focus of disease, *e.g.* pulmonary phthisis at the same time as disease of some joint, or of the testis, it is often found that no progress is being made towards recovery, in spite of what appears to be suitable treatment. It may then be advisable to remove, if possible, one of the foci, when steady, and perhaps rapid, repair may show itself in the other.

The manifestations and treatment of tuberculosis as it affects **special tissues and organs** are dealt with elsewhere under the appropriate headings.

The Treatment of Chronic Tuberculous Abscess must necessarily vary considerably according to the position and condition of the part. A superficial chronic abscess may be comparatively easy to treat, but the utmost caution is required, in order to avoid pyogenic contamination, when dealing with one placed deeply, and connected with such an affection as tuberculous disease of the spine.

1. In a few cases of superficial chronic abscess, especially when connected with lymph-nodes, it may be possible to *dissect out the whole cavity en masse*, and if this be feasible, it is the most satisfactory plan to adopt.

2. When the skin is thin and undermined, and the abscess nearly pointing, it is hopeless to avoid leaving an open wound; and hence the condition must be treated by the *open method*. The cavity is freely incised, diseased tissue scraped away, unhealthy skin removed, and the cavity treated with bismuth paste and completely closed. The incision should not be placed at the most dependent point of the abscess, because a sinus is likely to form should the abscess reappear. In some cases it will not be possible to close the cavity. The wound should then be packed with iodoform gauze and allowed to granulate upwards. Healing is often slow, but *a tuberculous abscess ought never to be allowed to reach a condition in which it is necessary to leave an open wound* of this type.

3. When a chronic abscess is situated deeply and covered with healthy tissues, treatment consists in evacuating the cavity in such a manner as to prevent the formation of a sinus, if possible.

This is best accomplished by means of *Aspiration*, the needle of the aspirator being introduced from the side when practicable. The most thorough aseptic precautions are, of course, maintained, and the vacuum should not be too complete, so as to avoid too rapid a withdrawal of the fluid, which might result in hæmorrhage. Slight external pressure will assist in emptying the abscess. If the fluid re-collects, the process may be repeated.

Sometimes the content of the abscess is so solid that it cannot flow through the needle, and then the latter should be withdrawn and replaced by a trocar and cannula of sufficient size to allow the cavity to be irrigated with warm saline solution (105° to 110° F.). The abscess wall is gently kneaded so as to detach curdy material and necrotic pyogenic membrane. This is continued until the escaping fluid is nearly clear or only slightly opalescent, and then the cannula

is withdrawn and a deep stitch introduced to close up the track. In this way it is often possible to cure a chronic abscess by one aspiration. The treatment is most likely to be efficacious when all active bone or joint disease has disappeared, and residual abscesses are the most favourable of all. Formerly this treatment was associated with the introduction of some drachms of a sterilized emulsion of iodoform in glycerine (10 per cent.), but it is doubtful whether this addition was really effective.

It is often a matter of considerable difficulty to secure the healing of a **tuberculous sinus**, owing partly to the presence of, say, diseased bone within it, partly to defective drainage, and also in part to the existence of tuberculous tissue in its wall; the added presence of a pyogenic infection will still further delay healing. If possible the whole tract should be excised, or, failing this, thorough curettage, so as to remove as much of the tuberculous material as is possible. Not infrequently sinuses of this type burrow widely, and it is sometimes difficult to ascertain their extent with a probe only. In such cases it may be helpful to inject the sinus with 'B.I.P.P.,' or with a paste consisting of bismuth subnitrate 1 part and white vaseline 2 parts, and to examine the extent of the lesion by radiography. Where there is much discharge, effective drainage must be provided, but efficient general treatment will usually secure healing in time, without recourse to operative measures directed to removal of the diseased bone, if present, which may come away in small spicules. It must also be borne in mind that, unless suitable and efficient treatment is adopted, amyloid or waxy disease may supervene in such cases.

Glanders.

Glanders is primarily a disease of the horse, ass, or mule, which is transmitted to man by direct inoculation, and hence is usually seen in stable attendants and those brought in contact with such animals. The disease is due to *Bacillus mallei*. In Great Britain the disease, both in man and animals, is now practically extinct, though laboratory infection has occasionally occurred.

In **Horses** and other animals glanders manifests itself by a formation of larger or smaller rounded swellings in the mucous membrane of the nose, which break down and ulcerate, giving rise to a thin, sero-purulent discharge, and perhaps to destruction of the bones and cartilages. The lymph-nodes, especially those under the jaw, early become enlarged, known to farriers as 'farcy buds,' which by their ulceration may leave ragged, foul, suppurating sores. The lymphatic trunks to and from the lymph-nodes are involved ('corded veins' or 'farcy pipes'), whilst the lungs and internal viscera may also be infected and undergo destructive changes. The disease is often chronic, lasting perhaps for years; any undue strain put upon the animal may lead to an acute exacerbation, which may be fatal in six to twelve days.

In **Man,** glanders generally starts about the hands and face, but occasionally in the nasal mucous membrane. In **acute** cases the incubation period lasts from three to five days, and is succeeded by

the occurrence of malaise and febrile disturbance, followed by severe pains in the bones and joints. The site of inoculation becomes red and swollen, whilst the lymphatics leading from this to the nearest lymph-nodes are enlarged and inflamed. An eruption of papules, which somewhat resembles that of small-pox or an iodide rash, occurs around the primary lesion, on the face, and in other parts of the body; but each papule, as also the primary lesion, breaks down and goes on to the formation of an ecthymatous-looking ulcer. It is not an uncommon feature of these sores, when situated over a bony surface, to involve the periosteum and lay bare the subjacent bone. Similar changes occur in the viscera, muscles, and joints, and these being associated with high fever of an asthenic type may suggest the existence of pyæmia. In such cases death may ensue in seven to ten days.

In **chronic** glanders similar symptoms are met with, but the course is slower; there is little or no fever; the disease is less extensive, and intermissions are not uncommon. It may affect the nasal mucosa, leading to chronic ulceration, but more commonly it appears in the shape of chronic abscesses which often extend deeply, even down to the bones, and are very difficult to treat.

It is important to make the **Diagnosis** as early as possible, in order to undertake energetic local treatment. The local lesions are distinguished from small-pox by the presence of the characteristic bacilli in the discharge, by the fact that they involve the subcutaneous tissues more extensively, and by the absence of umbilication. Chronic cases, showing nodules and ulceration, resemble syphilis and tuberculosis, but any history of exposure to infection from animals suffering from the disease is most important, as also the result of cultures made from the discharge. Inoculation of the peritoneal cavity of a male guinea-pig with some of the discharge leads to acute orchitis in two or three days, the testicles being enlarged and the skin over them reddened; the affection usually runs on to suppuration. Mallein, a sterilized and filtered broth culture of the organisms, may, like tuberculin, be used for diagnostic purposes in animals, the injection of a minute dose causing a sharp febrile reaction if glanders is present. Its use in man is not without danger.

Treatment in acute cases can be successful only when undertaken early, and before general infection has ensued. The local foci should be thoroughly extirpated, either by the knife, or by scraping and applying some active cauterizing agent. The same treatment must be adopted in chronic cases, and may then need frequent repetition. The use of immune serum and vaccine is also recommended by some authorities.

Leprosy.

Leprosy (*syn.:* Lepra or Elephantiasis Græcorum) is a general infective disease due to *Bacillus lepræ*, characterized by the formation of granulomatous masses which arise primarily in connection with the skin, mucous membrane, and nerves. Unlike the tuberculous granuloma, these nodules are vascular, contain no giant-cells, and are comparatively small in size in relation to the number of bacilli present.

The bacillus of leprosy resembles that of tuberculosis, and, like it,

is Gram-positive and acid-proof, staining readily by Ziehl-Neelsen's method, though more easily decolorized than are tubercle bacilli. Leprosy bacilli are usually smaller, straighter, and more uniform than those of tubercle; and when seen in sections of leprous material they are often present in far larger numbers than are the tubercle bacilli in tuberculous tissues; they are situated mostly within the large granulation-tissue cells ('lepra-cells') and often show a characteristic grouping as if packed together like bundles of cigarettes (Plate V., Fig. 6). Numerous attempts have been made to cultivate them, and successes have been claimed. Attempts to inoculate animals have failed, and this test constitutes the best and most definite method of differentiating between the two diseases. The Wassermann is sometimes positive.

Leprosy, though formerly common in this country, is now observed only in imported cases. In Iceland, Norway, Russia, and the East, it is still frequently met with, although the method of segregation of lepers enforced in Norway has greatly diminished the number in that country. Leprosy is occasional in the United States. It is common in the Hawaiian and Philippine Islands and also in the West Indies. It is apparently very slightly contagious to adults, the medical attendants and nurses in leper hospitals rarely contracting the disease; inoculation experiments on criminals have led to negative results. The children of leper parents are not diseased at birth, but are very liable to contract it at an early age; this fact emphasizes the urgent necessity for separating the children from their diseased parents at the earliest possible date.

Symptoms.—Two chief clinical varieties of leprosy exist, *viz.* the nodular, and the maculo-anæsthetic; but the two are often associated.

Nodular or Cutaneous Leprosy is the form seen most commonly in Europe. Nothing may be noticed for months or years after exposure to the contagion, and then, after a period of malaise, associated with dyspepsia, diarrhœa, and drowsiness, a distinct febrile attack is noted, lasting for days or weeks; it may be ushered in by a rigor, and the temperature is usually of a remittent type. This is followed by, or associated with, the appearance of shiny, red, hyperæmic spots, which are from the first infiltrated, slightly raised, and hyperæsthetic; they are situated usually on the forehead or cheeks, on the outer side of the thighs, or on the front of the forearms. They are due to the development of nodules of granulation tissue. They may fade away and disappear entirely, and then again become evident, or fresh patches may be developed, and always with febrile symptoms. After a variable period numbers of little pink nodules form over the site of one or more of the erythematous patches, and these gradually increase in size and coalesce, until possibly they become as large as a walnut or hen's egg, and are then of a brownish-yellow colour. Almost any part of the surface of the body may be invaded in this manner, but the face is especially prone to be involved, and the resulting disfigurement is very marked, a curious 'leonine' appearance being imparted to the features (Fig. 57). The mucous membrane of the mouth, pharynx, nose, and larynx are also often affected and prone to ulceration.

The nodules are more or less anæsthetic from the pressure of the infiltration on the nerves, and the ultimate result of the process may vary considerably; resolution sometimes occurs, or the nodules may be transformed into depressed and pigmented cicatrices, or ulceration may ensue (Fig. 58). Visceral complications—lepra-cells crowded with the bacilli being found, for example, in the spleen and liver—and enlargement of the lymph-nodes follow, any fresh deposit being associated with febrile phenomena. The sexual organs and their functions are usually affected in this form. Death may occur from general spread of the lepra bacillus itself, but is more commonly due to some intercurrent malady such as pneumonia, dysentery, renal disease, etc.; the patient may, however, live for many years.

Maculo-Anæsthetic Leprosy is the form more commonly met with in hot climates, and in it the nerves chiefly are the seat of a diffuse infiltration. The earliest phenomena consist in a certain amount of malaise without appreciable fever, together with sharp tingling or lancinating pains and tenderness along the course of certain peripheral nerves. The ulnar, median, peroneal, and saphenous nerves are those most often affected. This is followed by muscular weakness, progressing finally to paralysis, various modifications of sensation, and trophic phenomena, involving at first only the skin, but later on attacking bones, joints, and muscles. Circular yellowish-white patches are observed in the skin, spreading peripherally, and tending to run together, forming large irregular ovals; the border is often raised and hypersensitive, but the central portions become atrophic, dry, white, and anæsthetic. In the skin of these patches, the absence of the secondary dark red flush or 'flare' usually seen around the weal resulting from scarification of the normal skin with a 1 : 1,000 dilution of histamine phosphate in saline is said to be diagnostic of leprosy. The anæsthesia gradually spreads, and serious lesions, partly due to trauma, partly arising from trophic changes, result. The muscles atrophy and contract, and give rise to deformity, the hands sometimes becoming markedly 'clawed' as in ulnar paralysis. Interstitial absorption of the bones of the peripheral portions of the limbs may lead the fingers, toes, and other portions to shrivel and disappear, preceded by ankylosis of the joints. The affected nerves can usually be felt distinctly enlarged and tender. Visceral lesions are not so marked in this as in the other form of the disease, and the patient may retain a considerable degree of health and strength, while his sexual powers may still be retained. Finally he dies from general debility, or from various complications, but the case may last twenty or more years.

FIG. 57.—CASE OF LEPROSY.

Treatment.—The earlier in the disease this has been undertaken,

the more favourable have been the results obtained. The intravenous injection of ethyl esters of chaulmoogric and hydnocarpic acids, or of sodium hydnocarpate (' alepol '), sodium gynocardate ' C,' and other *derivatives of chaulmoogra oil has been used with marked success*, and also creosoted hydnocarpus oil given intramuscularly or subcutaneously, alternating with some of the foregoing. Treatment with a vaccine prepared from the bacilli contained in excised leprous tissues (Norman Walker), has also been favourably reported upon in a few cases. Treatment, to be effective, should be maintained for at least a year, and must be associated with good sanitary conditions, nourishing

FIG. 58.—A CASE OF LEPROSY BEFORE AND AFTER THE APPLICATION OF TRICHLORACETIC ACID (DR. MOISER'S CASE).

food, and protective dressings containing powdered chaulmoogra seeds in an ointment. The best way of treating nodules and infiltrations is to destroy them completely with repeated applications of trichloracetic acid (Fig. 58).

Actinomycosis.

Actinomycosis is a disease of man and animals, especially cattle, due to infection with various types of a group of streptothrices called actinomyces (or ray fungus), and invariably associated with a bacillus, *B. actinomycetem comitans*. The characteristic pathological process is the development of a granulomatous mass around a colony, which after a time breaks down, suppurates, and discharges pus containing small pale yellow to greenish-grey or brownish bodies, the so-called ' sulphur

granules.' The structure of these bodies can be made out by crushing the particles between two slides and staining the film thus produced. Each colony consists of a tangled mass of Gram-staining mycelium (Plate V., Fig. 7), the peripheral portion having usually a definite radial arrangement, whilst the centre often consists of necrotic material and granular debris. The mycelial filaments which project from the outer portion of the colony may show 'clubbing' from degenerative thickening of their sheaths.

The structure of the granuloma resembles in some respects that of a tubercle, giant-cells being perhaps less frequent, and the centre of the nodule occupied by a characteristic colony of the fungus. The disease tends to extend locally, but a pyæmic spread may supervene and important organs be attacked.

It is commonly supposed that the organism reaches both man and cattle on infected barley or other cereals, fragments of which may stick in the gums by the side of the teeth, or about the pharynx or œsophagus, or may be swallowed and infect some part of the gastro-intestinal tract. Fruit and other foods may be contaminated from infected straw in which they have been packed.

Actinomycosis in **Cattle** most commonly affects the tongue or jaw, and causes a chronic fibrosing inflammation ('woody tongue,' 'lumpy jaw,' of cattle) (Plate V., Fig. 8), often suppurating and producing multiple chronic abscesses, which discharge externally and leave a diffuse inflammatory mass riddled with sinuses.

In **Man** the disease occurs especially in farmers, millers, and others who are brought in contact with grain or with raw cotton, though it may be difficult to trace any such connection. In some cases the primary lesion may be in the neighbourhood of a carious tooth, from which the gums, tongue, cheek, lower jaw, or other neighbouring tissues may be infected; or the original site may be a tonsillar crypt. Less frequently it may occur in other parts of the alimentary canal, especially in and around the cæcum or appendix, or in the liver, giving rise to a characteristic reticulated swelling, in which diffuse suppuration may occur. It may come to affect the central nervous system, either as a meningitis or with abscess-formation; or it may attack the lung, causing lesions and symptoms which may simulate those of tuberculosis, and often giving rise to localized empyema. The skin may also be affected, but in the majority of cases only by extension from the deeper tissues.

The commonest site for the primary lesion, occurring in about 55 per cent. of cases, is close to the angle of the jaw, where it constitutes a *cervico-facial* lesion of characteristic appearance (Fig. 59). At first the mass has a smooth, regular and even surface, and merges gradually into the surrounding tissues, the skin over it being usually hyperæmic. The absence of involvement of the lymph-nodes is of important diagnostic significance. As time passes, little nodular excrescences, with a characteristic yellowish apex, form here and there on the surface of the mass, and these soften, point, and burst, giving exit to a small amount of thick gelatinous pus, in which the actinomyces may usually be demonstrated, though in some cases the

inoculation of animals may be required for the identification of the organism. When all the mycelium has been discharged, the abscess contracts and the wound closes. The cicatrization induced by the constant repetition of this process gives to the surface of the mass the peculiar nodular and puckered appearance which, when present, is almost pathognomonic. At other times sinuses persist, and the affected area may become riddled with them (Fig. 60). Trismus is an almost constant symptom in the cervico-facial form of the disease, coming on early, and being apparently independent of the size of the mass or its involvement of nerves. The abdomen is attacked in about 26 per cent. of the cases, the cæcum and appendix being the most frequent site to be affected. A diagnosis of appendix abscess or tuberculosis of the cæcum is usually made. The lesion is submucous at first, but later becomes secondarily

FIG. 59.—CASE OF ACTINOMYCOSIS WITH SINUSES AT THE ANGLE OF THE JAW.

FIG. 60.—ADVANCED CASE OF ACTINOMYCOSIS OF THE JAW.

affected, giving rise to softening and destruction of tissue. The abdominal parietes become involved and numerous fæcal fistulæ may form. The liver is also a common site, and presents on section a characteristic honeycombed appearance.

There is also a pulmonary variety (15 per cent.) which may simulate bronchitis, broncho-pneumonia, or miliary tuberculosis. Secondary involvement of the pleural ribs, sternum, and vertebræ is common. In rare cases the breast, kidney, and brain, the latter particularly so in association with the pulmonary type, may also be affected.

Treatment.—The most effective treatment in early cases consists in curetting away all dead and diseased tissue and leaving the wound open to promote drainage and to permit free access of oxygen to

the streptothrices, which are anaërobic organisms. Abscess cavities, when present, should be drained, iodides should be prescribed up to 240 grains daily, or more. They probably act by promoting absorption of fibrous tissue, thereby improving the blood-supply to the lesions. A more effective way of securing oxygeneration of the infected tissues is to pack the wound with freshly-made zinc peroxide paste. In the presence of water the peroxide is gradually broken down into the more stable oxide, with the evolution of nascent oxygen. Vaccine treatment holds out some prospect of help, the vaccine consisting of a stock, or preferably an autogenous growth of *Actinomyces bovis*, together with such other organisms as may be present in the secondary infections. For thoracic and abdominal cases X-ray therapy is often useful, and in those cases in which the lesions are accessible, teleradium or the insertion of radium may be effective.

CHAPTER VII.

TUMOURS AND CYSTS.

A TUMOUR may be defined as 'a mass, of new formation, that tends to grow or persist, without fulfilling any physiological function, and with no typical termination.' The fact that it has no typical termination distinguishes it from inflammatory overgrowths, which tend to form fibro-cicatricial tissue or some modification of it; inflammatory lesions, moreover, may disappear completely, and often diminish in size temporarily. Pure hypertrophies are excluded by this definition, since they depend upon some increased physiological function, and are composed of an increased development of normal tissues, as, for instance, the blacksmith's biceps.

The recognition of the primarily local origin of a cancer is the fundamental fact upon which has been built up the operative treatment of the disease, the success of which depends to a very large extent upon its early diagnosis. At present there is no certain means of diagnosis, except the clinical, and the microscopical examination of a portion of the growth removed for the purpose.

The prevention of cancer has attracted a great and growing amount of attention during recent years in view of the alleged increasing death-rate from this cause. This alleged increase may, however, be due in large part to the greater accuracy of modern diagnosis. Mortality statistics are at best still very unreliable. An all-important element in the direction of prevention is the avoidance of sources of irritation, whether local or general.

There are several well-known instances of cancer following continual irritation. The 'chimney-sweep's' cancer of the scrotum, the malignant papillomata of the bladder in dye workers, cancer of the lower lip due to clay-pipe smoking, and cancer of the skin of the lower abdominal wall and thighs of natives of Kashmir, due to the habit of hugging heated earthenware pots, are all examples of this influence. At the same time early attention to all slight local affections in the body is essential, *e.g.* patches of leucoplakia on the tongue or elsewhere, ulcers from rough teeth or dental plates, a torn cervix uteri, or a small lump in the breast. Regenerated tissue also appears prone to become the seat of malignant disease. To this end may be mentioned the frequency of the epitheliomatous change in scars and the supervention of carcinoma in the regenerating lobules of hepatic cirrhosis.

Finally there is the possible influence of the action of certain chemical substances allied or belonging to the sterol groups, which normally act as 'evocators' of the development of tissues and organs, but which may, under normal conditions, lead in the body of the embryo itself to the development of secondary or induced reduplications of structure

or of tumour growths which have hitherto been regarded as originating from another individual or twin.

Tumours may, from the clinical standpoint, be divided into two great classes, *viz.* the **benign** and the **malignant,** with, however, all intermediate varieties.

Benign or **Simple Tumours** are characterized by their more or less definite limitation, being frequently encapsuled, and by their method of growth. The surrounding tissues are merely pushed aside and compressed by the increasing growth of the tumour; pain and atrophy are sometimes caused by this pressure. The capsule is formed by an ensheathing layer of fibro-cellular tissue, the outcome of the chronic irritation engendered by the growth; hence enucleation may be easy, and recurrence uncommon. They are sometimes multiple, and may be congenital; but there is no tendency to the production of secondary growths. They cause no cachexia and do not threaten life unless developing in or upon some part whereby the vital functions are impaired.

Malignant Tumours, unless removed by operation or in some cases successfully treated by radio-therapy (pp. 303 and 308), are almost invariably fatal. The following are the chief characteristics of malignancy: (1) The primary growth is usually *single*, rarely multiple. (2) It *progresses continuously*, but with varying rapidity in different cases. (3) The local development is characterized by *an infiltration* of the surrounding tissues, which are gradually destroyed and replaced by the tumour. A capsule is rarely formed, or, if at all, only in the early stages, and thus the limits of the growth are not clearly defined. Moreover, many varieties spread locally along the lymphatics draining the area involved, and hence, although the growth may appear to have been completely excised, 'recurrences' are very common, owing to the non-removal of these invisible extensions of the disease into apparently normal tissues. If a malignant tumour with all its ramifications is completely removed, it does not recur. (4) When a malignant tumour invades the skin or a mucous membrane, it usually leads to *ulceration* and is very liable to secondary infection with micro-organisms, and then not uncommonly a foul fungating mass results. (5) *Metastases* due to embolic dissemination of the cells of the growth are often found in neighbouring lymph-nodes or distant viscera. (6) *Cachexia* usually develops in the later stages, due partly to the pain, partly to the pressure of the growth on important structures, and in part to the absorption of toxic products from the tumour. The patient becomes thin and emaciated, the face drawn and with an expression of pain; the appetite is impaired and the skin often sallow and earthy-looking. Pyrexia may be absent unless ulceration of the growth occurs, as is commonly the case when the stomach or intestine is affected; some rapidly-growing sarcomas of bone are also associated with fever. (7) Finally, *death* results after a longer or shorter period.

The **degree of malignancy** varies with different types of tumour and also with the nature and site of their origin. In some the local phenomena predominate, whilst in others the phenomena following upon

their dissemination are the more important. Thus, rodent ulcer is slow in its progress, and produces no visceral metastases; if it destroys life it does so merely by extension of the primary growth to vital parts. A malignant melanoma, on the other hand, may produce only a small primary growth, but the most extensively diffused metastases may form in the viscera. The sarcomas are usually disseminated by the blood-stream, and hence secondary growths are not so common in lymph-nodes, whilst the carcinomas spread especially by means of the lymphatics.

In some cases gravity also aids the spread of cancer cells. Cells from a carcinoma of the stomach may reach the peritoneal surface and gravitate across the abdominal cavity to the pelvis, giving rise to enlargement of both ovaries (Krukenberg tumour) from secondary deposits.

As a general rule malignant tumours differ structurally from the innocent forms in deviating more widely from the normal histology of the tissue in which they develop; thus, a simple fibro-adenoma of the breast approaches more closely to the structure of the normal mammary gland than does an adeno-carcinoma of the same region. This deviation from the normal is called **anaplasia,** and in general the greater the degree of anaplasia the greater the malignancy.

Classification of Tumours.—Of the various classifications which have been suggested, that of Adami is the simplest and most convenient. The introduction by him of many new terms has militated against its general adoption, but, omitting these as perhaps unnecessarily complicated for a textbook of surgery, we shall utilize it here in a simplified form. Two main groups of tumours are first distinguished:

A. **Blastomas** or **Body-Tissue Tumours** have been defined as tumours 'composed of the product of aberrant growth of the cells and tissues of the individual in whom they are developed.'

This group of **Body-Tissue Tumours** is then further subdivided. From each of the three primitive embryonic layers, epi-, meso-, and hypo-blast, are derived two types of tissues: *pulp-tissues,* in which the specific cells lie in, and are separated by, a definite stroma; and *rind-tissues, i.e. covering-* and *lining-tissues,* in which the individual cells are not separated by a stroma and in which the blood-vessels do not penetrate the groups of specific cells. From each of these series of pulp- and rind-tissues respectively tumours both simple and malignant may grow. The pulp-tumours derived from all three embryonic layers exhibit so many analogies, both clinical and pathological, that they may be considered together, and a similar classification of the rind-tumours may be made. Each of these series of pulp- and rind-tumours may further be divided into those which are *simple* and those which are *malignant* (with the proviso that, both clinically and histologically, all intermediate stages between definitely 'simple' and definitely 'malignant' tumours occur.

B. **Teratomas,** or tumours 'composed of the products of one individual within the tissues of another individual of the same species.'

A. **Blastomas (Body-tissue Tumours).**

I. **Pulp-tumours.**

(1) *Simple or Typical:*

Fibromas.	Odontomas.
Myxomas.	Osteoclastomas or Giant-cell Tumours.
Lipomas.	Lymphomas.
Chondromas.	Myomas.
Chordomas.	Gliomas.
Osteomas.	Neuromas.

(2) *Malignant or Atypical* (*'Sarcomas'*) *:*

The malignant tumours corresponding to the foregoing simple tumours, together with those derived from *meso-* and *endo-thelial* tissues, in which there has occurred reversion to 'pulp' characters. (Along with this group will, for convenience, be considered the *melanomas*, pigmented tumours of doubtful origin.)

II. **Rind-tumours (derived from Covering and Lining Tissues).**

(1) *Simple or Typical:*

Epithelial:	*Endothelial:*
Papillomas.	Hæmangiomas.
Adenomas.	Lymphangiomas.

(2) *Malignant or Atypical:*

Epithelial:

Cancers or carcinomas (including Malignant Papillomas, Epitheliomas, Malignant Adenomas, etc., along with which Hypernephromas, Chorionepitheliomas, and Adamantinomas may be included).

Endothelial:

Endo-, Meso-, and Peri-theliomas, etc., in which the 'rind' characters persist.

B. **Teratomas (including Placentomas and Teratoid Tumours).**

A. Blastomas or Body-tissue Tumours.

I. Pulp-tumours.

(1) Simple or Typical.

Fibromas consist of neoplastic overgrowths of fibrous tissue; they are usually divided into two groups, the **hard** and the **soft**, and, although there is no essential difference and all intermediate varieties occur, it is a useful clinical distinction.

The **Hard Fibroma** is composed of firm dense tissue, the cut surface of which shows numerous trabeculæ of glistening fibres, somewhat similar in appearance to those present in a tendon (Fig. 61). They are painless tumours, unless they give rise to pressure on nerves or other structures, and usually they shell out easily at operation. Microscopically, interlacing fibrils are seen, which are sometimes arranged concentrically around the blood-vessels. In these more slowly-growing tumours the connective-tissue cells are comparatively few in number, narrow, spindle-shaped, and with scanty protoplasm and rod-like nuclei (Fig. 62). Blood-vessels are usually scanty, thin-walled, and lacking in muscular tissue, and of the nature of capillaries or capillary-venous spaces. Similar thin-walled, dilated veins may, however, be found in the capsule, and sometimes in the substance of the mass; these, or the thin-walled capillary blood-spaces, if opened by ulceration, may lead to profuse hæmorrhage. Hard fibromas may occur in many situations, but especially in the breast and ovary, and in tendons, the cerebral membranes, not uncommonly in the sheaths of nerves, or as fibrous polypi of the naso-pharynx, as one variety of epulis, or in the form of keloid.

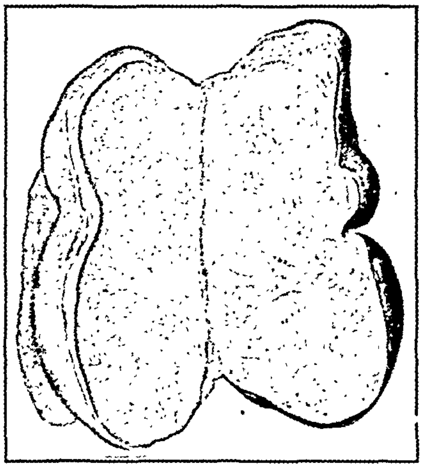


FIG. 61.—SECTION OF HARD FIBROMA. (ROYAL COLLEGE OF SURGEONS MUSEUM.)

Soft Fibromas develop as localized overgrowths of the subcutaneous or other fibro-cellular tissues, and may be slow or rapid in their development, and in the latter case somewhat resemble a sarcoma (Fig. 63). Sometimes, when occurring on the body-surface, they become more or less pedunculated, constituting what is known as *molluscum fibrosum*, and then may appear as rounded, smooth-topped nodules; or may be pink in colour and covered with somewhat corrugated skin, looking like a nipple; or may develop into large pendulous folds. Such 'molluscous' tumours are not unfrequently multiple, and are then usually a manifestation of neuro-fibromatosis or von Recklinghausen's disease.

Recurrent Fibroid (**of Paget**) is a variety of fibroma which is found in muscle sheaths and which tends to local recurrence after excision. Although it has the appearance microscopically of being a fibroma it is really a fibro-sarcoma of low malignancy. The **Desmoid**, a type of fibroid tumour occurring most frequently in the rectus abdominis muscle in middle-aged women, is an example of a tumour of this sort.

Myxoma.—A myxoma is a tumour consisting of connective-tissue cells, surrounded by and separated from each other by an intercellular substance of a mucoid or jelly-like character; a similar type of material occurs normally in the substance of the umbilical cord. The cells are usually triangular or stellate in shape, and present long branch-

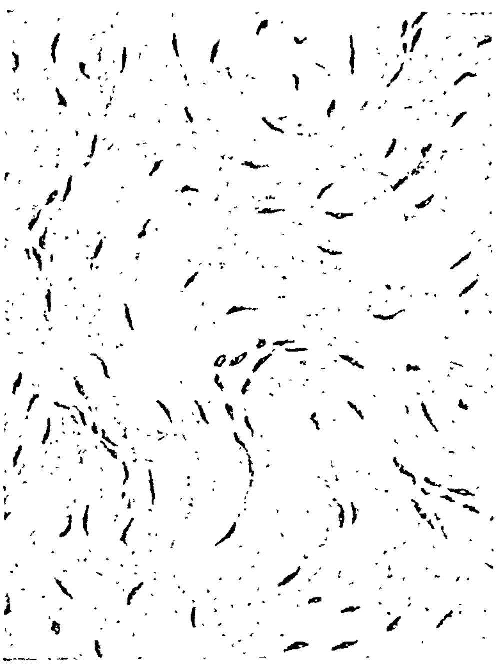


FIG. 62.—HARD FIBROMA, SHOWING DENSE FULLY-FORMED FIBROUS TISSUE, WITH CAPILLARY BLOOD-SPACES LINED BY ENDOTHELIUM. (×300.)

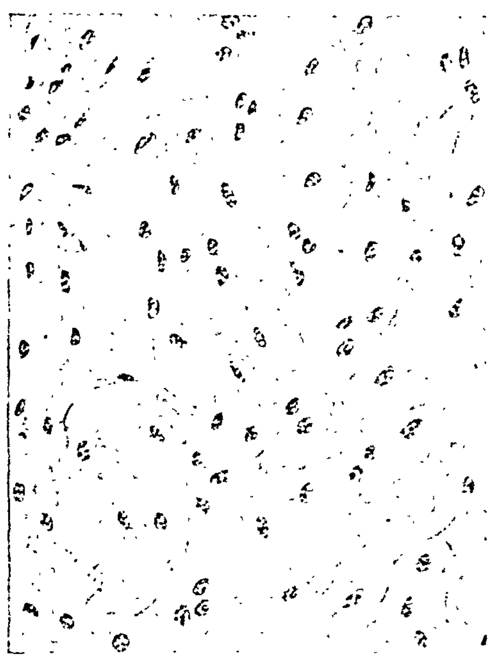


FIG. 63.—SOFT FIBROMA, SHOWING LESS FULLY-FORMED FIBROUS TISSUE THAN IN THE HARD FIBROMA OF FIG. 62. (×300.)

ing processes which interlace with those from adjacent cells. The intercellular substance is homogeneous and translucent, and is traversed by imperfectly formed blood-vessels; the density of the tumour varies inversely with the amount of intercellular substance. It is not uncommon for a similar mucoid or myxomatous condition to occur as a secondary change in fibromas, lipomas, and chondromas, and also in sarcomas, from which it is often difficult or almost impossible to differentiate them histologically, and hence a thorough and early removal of the mass is always advisable. An analogous mucoid (or colloid) change may also supervene in the stroma of some glandular tumours, or may involve the epithelial cells themselves.

Myxomas occur as irregularly rounded tumours, perhaps lobulated,

especially in the subcutaneous or submucous tissues, *e.g.* of the breast, face, intestine, and bladder; they also grow in the sheaths of nerves.

Lipoma.—A fatty tumour is an overgrowth of fatty areolar tissue. On microscopical examination it differs little from ordinary adipose tissue, but is usually not so freely supplied with blood-vessels.

(1) When **localized** (Fig. 64) it forms a tumour, soft and semi-fluctuating in consistence, rounded and lobulated in outline, and, if occurring in the subcutaneous tissues, the skin becomes dimpled on moving it from side to side, owing to the fact that fibrous trabeculæ pass from the septa and capsule to the skin. The growth is usually encapsuled and freely movable; but, if exposed to pressure or friction, it may become firmly adherent to surrounding structures. The swelling has a definite edge and is quite painless. Such growths are either single or multiple, in the latter case perhaps occurring even in hundreds, and are most commonly found about the trunk or the upper extremities. Occasionally subcutaneous tumours become pedunculated and pendulous, especially about the upper part of the thigh.

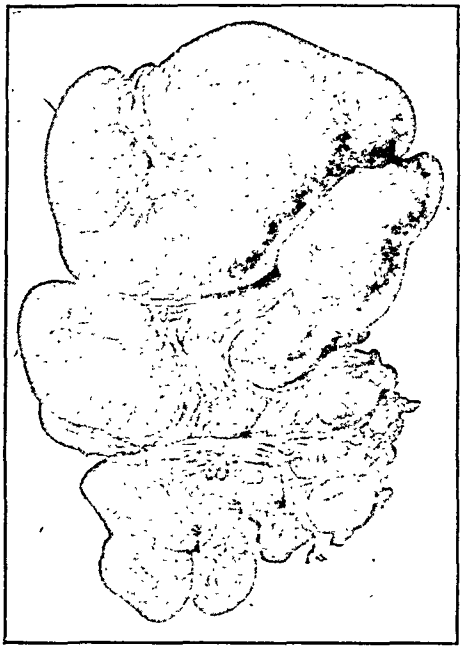


FIG. 64.—LIPOMA, SHOWING CHARACTERISTIC LOBULATED OUTLINE.

The diagnosis of a subcutaneous lipoma from a chronic abscess is made by noting that in the former there is a defined outline of a lobulated character, that the edge slips away on making pressure over it, and that the skin dimples on moving the growth from side to side. In a chronic abscess the swelling is less defined in outline, has a shelving margin, and the skin is either quite free or adherent over a considerable area. Fluctuation is present in both, since fat at the temperature of the body is fluid.

Deep intermuscular lipomas occur, and the diagnosis is often difficult, since their mobility and lobulated outline are masked by the superjacent tissues; they are liable to be mistaken for sarcomatous growths. Still more difficult of recognition are those known as **Parosteal Lipomas,** growing from the outer surfaces of the periosteum. They are often congenital, and appear as soft swellings, lying beneath the muscles in close proximity to a bone, and suggesting the presence of a chronic abscess.

Submucous Lipomas also occur, and are most frequent in the larynx, pharynx, and in the intestine, where one may occasionally form the starting-point of an intussusception. In the larynx these tumours have been known to cause respiratory obstruction.

Subsynovial Lipomas are similar in nature and arise from the soft fatty tissue lying around the joints; when single they may be mistaken for the cystic evaginations of the synovial membrane known as Baker's cysts. In osteo-arthritis a diffuse formation of small multiple lipomas is sometimes seen, and is called **Lipoma Arborescens.**

Subfascial Lipomas are found under the palmar and plantar fascia, and are often mistaken for swellings of the tendon sheaths. They are often painful, particularly when in the foot, and they may require removal by operation on account of that factor.

Extradural Lipomas are sometimes found within the spinal column, and give rise to the onset of a slow pressure paraplegia.

The **Pericranial Lipoma** is of a somewhat similar nature. It is usually congenital in origin, and the cranium may be hollowed out beneath it. An angiomatous element is sometimes present in these growths (nævo-lipoma).

Localized overgrowths often occur in the subperitoneal fatty tissue, constituting **Subserous Lipomas.** They are not unfrequently found in the lower part of the abdomen, and may extend into the inguinal and crural canals. By their traction a process of peritoneum may eventually be drawn down, and a true hernia produced. A similar condition occurs in the anterior abdominal wall, small pedunculated masses of fat projecting through congenital or acquired openings in the linea alba often just above or below the umbilicus, or in the linea semilunaris; these, which are not usually neoplastic in nature, are known as **Fatty Herniæ of the Linea Alba,** and are often painful.

FIG. 65.—DIFFUSE LIPOMA.

Occasionally the connective-tissue basis of a lipoma undergoes modifications, *e.g.* it may become increased in amount and fibrous in character, and often very painful; or it may be associated with a myxomatous element, or even become sarcomatous. For nævo-lipoma, see p. 369.

(2) By the term '**Diffuse Lipoma**' or Lipomatosis (Fig. 65) is meant a fatty infiltration, rather than a true fatty tumour, of the subcutaneous tissues of some region of the body, particularly beneath the chin and at the back of the neck, and more rarely in the pubic region. These masses are often multiple and almost always symmetrical. They usually occur in those who drink beer freely and take little exercise. The condition may be associated with disturbance of endocrine functions.

Another variety which is distinguished by the appearance of multiple localized overgrowths of fat occurring particularly on the shoulders and limbs of women is painful, so that the condition has acquired the title of Adiposa dolorosa (Dercum's disease).

The **Treatment** of lipomas consists in their removal when necessary. When they are loosely encapsuled this is a simple matter, all that is required in many cases being to squeeze the mass forwards between the thumb and finger, making the skin tense over it, and then to incise the capsule freely, when the tumour is almost automatically extruded; but if there are many adhesions the removal may not be easy.

Chondroma.—Cartilaginous tumours grow in connection with either bone or cartilage. They consist of hyaline cartilage, which, instead of being uniform in texture and devoid of vessels, as at the articular ends of bones, occurs in the form of islets or nodules of varying size, held together by vascular connective tissue, which may penetrate into its substance. They are always lobulated because growth takes place from so many centres. The cartilage-cells are also less regular in shape than is the case with normal cartilage, and are not arranged according to any definite plan.

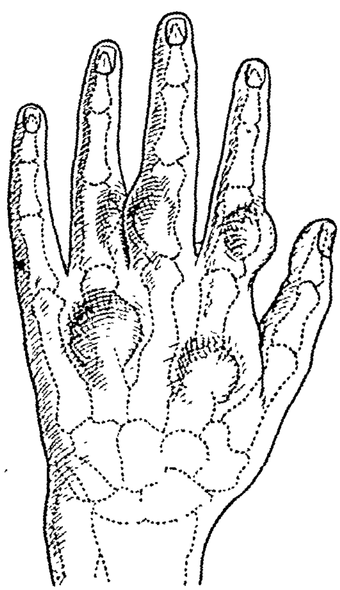


FIG. 66.—MULTIPLE ENCHONDROMAS OF THE BONES OF THE HAND.

Chondromas are liable to become calcified, and even ossified. When large, the central parts may undergo a mucoid change (see p. 191), giving rise to a cavity which, if infection is admitted, becomes exceedingly foul. They are sometimes complicated in their growth by sarcomatous degenerations.

Two varieties are met with according to whether growth occurs within or on the surface of the bone.

(1) **Ecchondroma.**—Clinically, two varieties of ecchondromas are met with: (*a*) The **large solitary ecchondroma,** arising usually at one or other end of a long bone or rib, but not appearing to be connected with the epiphyseal cartilage. The most frequent site for these tumours is the upper or lower end of the femur or the upper end of the humerus, but they also attain great proportions when growing from the pelvic bones, particularly the ilium. (*b*) A form of **multiple ecchondromas** which occurs in connection with **dyschondroplasia,** a disease associated with irregular ossification of the epiphyses resulting in enlargement of the growing ends of the bone. Very often these multiple cartilaginous masses become ossified.

Overgrowth of cartilage, known as **Ecchondroses,** may occur around the articular cartilages in connection with osteo-arthritis; they arise, also, from the cartilages of the ribs, or nose, larynx, etc. Some of the loose bodies which form in joints are of a similar nature. These,

though probably not originally neoplastic in nature, may become so.

(2) **Enchondromas.**—These are usually multiple, and are met with most commonly in the small bones of the hands and feet in young people (Fig. 66). The growth commences within the interior of the bone in the cancellous tissue of the metacarpals or phalanges, causing at first a fusiform enlargement and later a definite lobulation. The X-ray picture is characteristic, as the chondromata show up as clear spaces (Fig. 67). A rare variety of multiple enchrondromas is seen in **Ollier's disease** (hereditary deforming dyschondroplasia). This is a condition of the growing ends of bone in which certain areas of cartilage fail to ossify, so that as the bone grows these cartilaginous areas progress towards the centre of the shaft. It is a unilateral condition and affects chiefly the long bones.

FIG. 67.—SKIAGRAM SHOWING MULTIPLE ENCHONDROMAS OF THE BONES OF THE HAND.

Treatment consists in removal of the growth if not too large or multiple. In the case of enchondromas, it will be necessary to split the shaft to accomplish their removal. When removal is not practicable, or when malignant change has supervened, amputation is the only alternative. Radium treatment is of no avail.

Chordoma.—This is a rare form of tumour developing from remnants of the notochord, and may be found growing from the basi-sphenoid or basi-occipital bones, or from the vertebral column, especially at its lower end. Analysis of the recorded cases shows that approximately 60 per cent. occur in the region of the spheno-occipital synchondrosis, about a third occur in the sacro-coccygeal region, and tumours have occasionally been reported from the occipital region, dorsal spine, lumbar spine, and mandible. The majority occur in men and women of middle age, though the condition has been found at birth, and in patients of over seventy. The average age in spheno-occipital cases is thirty-five years, and in sacro-coccygeal cases fifty years. Males are affected more commonly than females in the proportion of two to one. These tumours are composed of characteristic 'vacuolated' cells containing mucin—the so-called 'physaliphorous' cells—embedded in a matrix often resembling that of hyaline cartilage.

Osteoma.—Bony tumours are of two chief forms: the cancellous and the ivory.

(1) **Cancellous Osteomas** usually occur near the articular end of a bone, being derived originally from some isolated portion of the

epiphyseal cartilage, which has perhaps been separated from its original connection after an attack of rickets. If such an island is situated near the periphery of the bone, it may develop into a tumour, pedunculated or sessile, which consists of cancellous bone, capped by a layer of hyaline cartilage, from which it grows (Figs. 68 and 69); and such a tumour may attain to a large size, leading to considerable deformity. It develops in young people before ossification of the epiphyseal cartilages is complete, and may be congenital. As the individual grows, the basis of attachment may become separated from the epiphysis to an extent corresponding to the amount of local growth which has taken place, or it may remain attached to the diaphysis close to the epiphyseal line. As a rule its growth and development cease at maturity, when the cartilage covering it, as well as the epiphyseal cartilage, ossifies. A bursa occasionally forms over the most prominent part of such an outgrowth as a result of friction or pressure, giving rise to the condition known as exostosis bursata; the cavity of this may communicate with the joint. An effusion of blood or serum into the bursa may be the first evidence of the existence of such a growth. The commonest situation for such a bony projection is the inner condyle of the femur, close to the adductor tubercle, and it may cause discomfort, especially in riding. The upper end of the tibia is sometimes affected, and, when the growth develops on the inner side of that bone, painful locking of the knee may occur from hitching of the tendons over the neck of the growth. The subungual exostosis (Fig. 70) develops as a rounded, cherry-like swelling under the nail, especially that of the great toe. It is very painful, and should

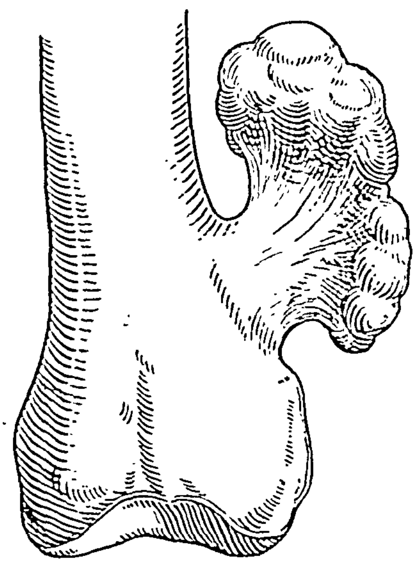


FIG. 68.—CANCELLOUS OSTEOMA OF LOWER END OF FEMUR (SEMI-DIAGRAMMATIC, FROM A RADIOGRAPH).

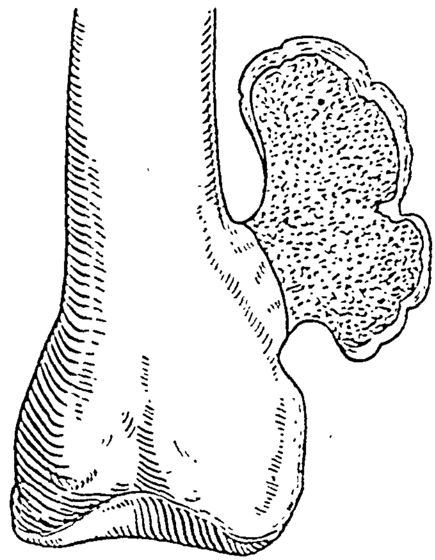


FIG. 69.—THE SAME, WITH OSTEOMA DIVIDED LONGITUDINALLY TO SHOW THE EXTENT OF THE INVESTING CARTILAGE.

be treated by removing the nail, incising the tissues over it down to the bone, and cutting it completely away.

Diaphyseal Aclasia is a condition in which multiple osteomas develop in the long bones, particularly near the growing ends. The swellings are symmetrical and usually grow slowly until maturity. They are painless and very seldom give rise to symptoms except through pressure. As a rule three main pathological features are recognizable: (*a*) There is growth retardation, softening and, rarely, cystic formation. (*b*) Proliferative changes take place on each side of the epiphyseal line leading to enlargement and deformity of the ends of the bones. (*c*) Small nodules are present along the course of the shaft of the bone. There is often some disturbance of the calcium metabolism.

According to Keith, the condition is due to defective limiting by the periosteum due to the fact that its growth does not keep pace with that of the shaft.

(2) **Ivory Exostoses** develop most frequently on the inner or outer aspect of the cranial bones, affecting especially the orbit, external auditory meatus, antrum, and frontal sinus (Fig. 71). They consist of masses of very dense compact tissue, covered by periosteum, from which they grow. They are usually lobulated, and, when situated in the frontal sinus, or growing from the inner surface of the skull, may give rise to serious symptoms from irritation or compression of the brain or its membranes. Occasionally necrosis of the tumour supervenes, followed by sloughing and separation of the mass, this bringing about a spontaneous cure.

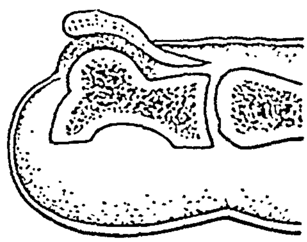


FIG. 70.—SUBUNGUAL EXOSTOSIS.

Diffuse overgrowths of the bones of the skull (**Hyperostoses**) may occur, affecting either the calvarium alone, being then probably syphilitic in nature, or the facial and cranial bones, as in leontiasis ossea. New formation of bone, probably inflammatory in origin, also occurs in the substance of muscles and tendons which are exposed to irritation or excessive action, *e.g.* the tendon of the adductor longus in riders, producing what is known as 'the rider's bone.'

The **Treatment** of osteomas consists in their removal when necessary. This may be simple in the case of cancellous osteomas of the limbs, but the extirpation of some compact exostoses of the calvarium may be a more formidable proceeding. The fact that cancellous osteomas usually cease to grow when the patient reaches maturity explains the rule of surgery that they need not be removed unless causing pain or mechanical inconvenience by their size. If such removal is undertaken, the tumour is chiselled or sawn away from its attachment to the bone, special attention being directed to the total removal of any covering cartilage, from which growth might otherwise continue.

Compact osteomas of the cranium may be separated and removed by chiselling away the bone around them, but occasionally a burr driven by electricity is required in order to divide their attachments.

Their removal, however, should not be attempted unless they are causing obvious symptoms.

Odontomes.—An odontome is a tumour composed of dental tissues which are concerned in tooth development. Odontomes must be regarded as tumours, as they tend to increase in size, perform no physiological function, have no typical termination, and fulfil Thoma's definition of a tumour, namely 'an autonomous or independent new growth.'

FIG. 71.—SKIAGRAM SHOWING OSTEOMA GROWING FROM THE FRONTAL SINUS, AND ENCROACHING ON BOTH THE ORBIT AND CRANIAL CAVITY.

As the tooth is derived from epiblast (enamel organ) and mesoderm (cement substance and dentine), odontomes may consist of either or both of these tissues. There are three main varieties—namely, epithelial, mesodermal, and composite.

The classification given by Bland-Sutton is still in common use, although it has been modified by the British Dental Association. The two classifications are compared side by side in order to allow the main differential points to be followed at a glance.

Classification of Odontomes.

	Bland-Sutton.	British Dental Association.
	Follicular odontome or dentigerous cyst.	Follicular odontome or dentigerous cyst.
Epithelial :		
	Compound follicular cyst.	
	Multilocular cyst (fibrocystic disease).	Multilocular cyst (fibrocystic disease).
	Fibrous odontome.	Fibrous odontome.
Mesodermal :		
	Cementome.	Cementous odontome.
	Composite odontome.	Complex composite odontome. Compound composite odontome.
Composite :		
		Germinated composite odontome. Gestant composite odontome. Dilated composite odontome.
	Radicular odontome.	Enamel nodules.

1. **Epithelial Odontomes.**

(*a*) **Follicular Odontome or Dentigerous Cyst.**—This is a unilocular cyst lined with stratified epithelium. It probably originates in paradental rests, or the remains of Nasmyth's membrane. It is most frequent in the lower jaw, and is always associated with an unerupted permanent tooth, usually a molar or canine. It is common to find such a cyst in rickety children. Possibly the cause is an infection from a deciduous tooth, which leads to the formation of a dental cyst. The cyst so formed meets and surrounds the developing unerupted tooth. A large swelling occurs in the jaw, painless at first, but causing some chronic pain as expansion of the bone takes place. Skiagrams reveal the missing tooth lying within the cyst, or in some cases embedded in the cyst wall.

(*b*) **The Compound Follicular Cyst** is a follicular (dentigerous) cyst which arises in connection with more than one tooth and is more common in the upper jaw. The treatment consists in opening the cyst and removing the infected tooth or teeth. The cavity should be washed out with tincture of iodine and treated as a dental cyst (*vide infra*).

(*c*) **Multilocular Cyst (Fibrocystic Disease of the Jaw, Adamantinoma, Cylindroma of Jaw).**—This tumour arises from the paradental epithelial rests (débris of Malassez), which lie along the developmental course of the tooth. It is very similar in structure to the adamantinoma found in the pituitary region, and when typical it is possible to recognize an outer layer of cells resembling the basal cells of the epithelium, and an inner mass of 'star-cells,' which undergo vacuolation and, later, mucoid degeneration. The stroma contains fibroblasts and, sometimes, giant-cells, and may show hæmorrhagic areas.

The tumour is more common in the lower jaw, and is of slow growth, gradually distending it but producing no marked change in the appearance of the mucous membrane. As the tumour grows it tends to become extruded from the outer plate of the alveolar border. If the tumour is allowed to grow to a large size, a thin layer of bone may cover the cystic spaces of the growth and eggshell crackling may be elicited.

This type of tumour may also occur in the pituitary region, where it is thought to originate in the epithelium of Rathke's pouch. An adamantinoma has also been found in the tibia, although its presence there is incapable of explanation.

Dental Cyst.—This is a very common form, and is commoner in the maxilla than the mandible, and seems to prefer the region of the first molar tooth. A dental cyst may occur in either sex, and may arise in connection with either deciduous or permanent teeth.

The actual cause of these cysts is an infection from organisms in the pulp canals of pulpless teeth. In some cases trauma may be the exciting cause where a small apical hæmatoma forms which becomes infected.

A dental cyst may arise through the irritation of epithelial cells in alveolar dental periosteum (the remnants of the epithelial sheath of Hertwig). The actual pathology is of interest in so much as the cyst begins as a granuloma in which the epithelium proliferates and

a so-called 'epithelial root tumour' develops. A capsule is formed lined by epithelium which may be squamous, stratified, or columnar in type. As the cyst grows it causes pressure on the bone surrounding it, the result being a bulging of thinned bone, which may become so attenuated that eggshell crackling may be felt on examination. X-ray examination invariably reveals a sharp outline to the cyst, except in those cases where an abscess has formed. As a rule there is a zone of rarefying osteitis surrounding the cyst wall.

The treatment of a dental cyst demands the extraction of the tooth which has been responsible for the cyst.

For a small dental cyst the cavity should be curetted and swabbed out with tincture of iodine to destroy the epithelial lining. The cavity should be irrigated daily with an antiseptic until healing has taken place.

In the case of a large dental cyst where an extensive cavity remains and healing would take a long time, a flap of muco-periosteum is raised and stitched to the bottom of the cyst. Such an operation could be undertaken only where there is no oral sepsis.

2. **Mesodermal Odontomes** consist of the fibrous and cementous odontomes. The **Fibrous Odontome** is very rare in man and resembles a hard fibroma. It may be due to hypertrophy of the tooth sac, or to fibrosis around a dentigerous cyst, and only occurs in association with an unerupted tooth. The **Cementome** may be due to excessive development of cementum or to calcification of a fibrous odontome. The tooth is embedded in a hard calcified mass. Suppuration may occur, resulting in the detachment of the tumour from the jaw. Excision may, however, be required.

3. **Composite Odontomes** are rare tumours consisting of a hard lobulated mass composed of enamel, dentine, and cement. On account of their hardness they are fairly easily removed.

The term 'complex' refers to the ordinary variety which is complex in composition. The 'compound' composite variety implies the involvement of more than one tooth. The 'geminated' variety results from malformations of two or three teeth. The 'gestant' composite odontome implies a denticle within a tooth, and the dilated composite variety denotes a dilatation within the tooth, but external to the pulp cavity. The **Radicular Odontome** (enamel nodule) consists of an irregular mass arising in connection with the roots of an apparently normally erupted tooth. It is generally composed of dentine covered with thick enamel.

Osteoclastoma or Giant-Cell Tumour.—This tumour was formerly described as a myeloma. It is not derived from the hæmatopoietic marrow-cells, but from osteoclastic and allied cells. It should, therefore, *not* be classified as a 'myeloma.' It has now come to be regarded as *comparatively* 'benign' in its nature, though in not a few cases the growth may extend rapidly by infiltration of the bone-marrow, *i.e.* is then definitely though locally **malignant**—and sometimes actively so. It is characterized by the presence of large numbers of multinucleated giant-cells (myeloplaxes), embedded in a groundwork of round or spindle-cells, the intercellular substance being usually of a gelatinous consistence (Fig. 72). The myeloid giant-

cells vary in size, but always contain many nuclei, which do not have the tendency to a peripheral distribution in the cytoplasm, as is usually the case in the giant-cells of tubercle. They may be regular in outline, or prolonged into numerous interlacing processes, although these latter are usually not very evident. There is also no arrangement of lymphocytes and epithelioid cells around them, as in the tuberculous giant-cell systems. These tumours are soft in consistency, and on scraping a slimy fluid is obtained. They are very vascular, and may pulsate. Hæmorrhage into their substance is common, giving rise to pseudo-cysts, filled with serum and a yellowish fibrinous clot. When freshly cut, the growing edge is of a dark maroon colour on section, and has been likened to the appearance of a pomegranate. Though infiltrating locally, as noted above, they seldom give rise to metastases at a distance. Their growth is often rapid, and they may attain enormous dimensions. Several varieties may be recognized: The **myeloid** type containing the usual type of giant cell in a spindle-celled stroma with varying degrees of telangiectatic and cystic formation; the **telangiectatic** variety in which large blood spaces lined with endothelium are prominent; the **cystic** variety in which numerous spaces filled with mucilaginous material form the most prominent pathological feature; the **xanthomatous** type is a solid tumour, yellow in colour, due to the presence of cells loaded with lipoid, probably a cholesterol ester; the **fibrous** variety in which the stroma is markedly fibrous with scanty giant-celled formation and poor vascularity; the **sarcomatous** variety consisting of masses of multinucleated, undifferentiated protoplasm occurring in a stroma of round cells. It may be periosteal or medullary in type; the former is seen in the jaws as one variety of epulis, and the latter is found in the lower end of the femur or upper end of the tibia. For particulars as to their clinical characters, see Chapter XXI.

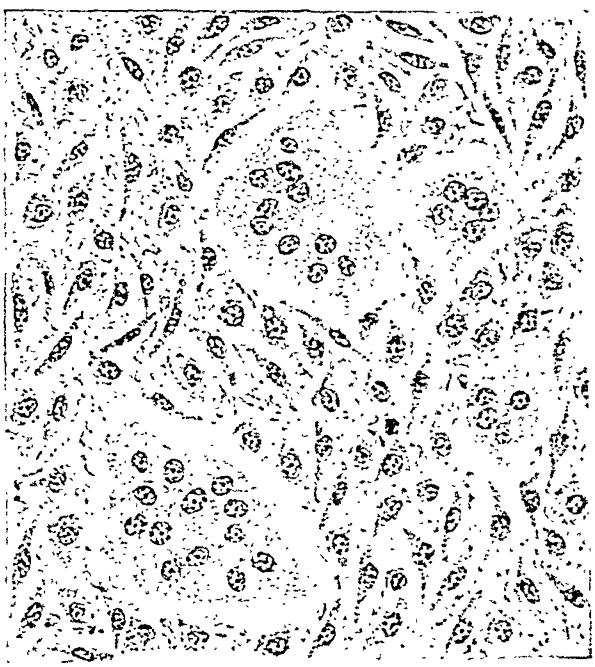


FIG. 72.—OSTEOCLASTOMA (SOMETIMES CALLED 'BENIGN MYELOMA') OF BONE, SHOWING THE LARGE MULTINUCLEATED GIANT-CELLS OR MYELOPLAXES, LYING AMONGST THE MORE ABUNDANT SPINDLE-SHAPED AND IRREGULAR CELLS. (× 300.)

Diffuse Myelomatosis, or **Multiple Myeloma,** is a condition in which there is patchy transformation of the marrow of the vertebræ, sternum,

and ribs, and less commonly the long bones, into a structure resembling that of myeloma. The bony tissue is absorbed, and deformity or spontaneous fracture may result. It is often associated with the presence in the urine of the 'Bence-Jones protein,' regarded by some writers as an albumose, which is precipitated at a comparatively low temperature (55° C.) and redissolved on boiling. The symptoms are pain, anæmia, and fever. The pain may be very severe, particularly when the spine and skull are affected. The anæmia develops as the marrow gradually gets replaced by the myelomatous deposits. The tumour-cells may resemble myeloblasts, erythroblasts, or plasma-cells respectively, and such tumours are unaccompanied by any leukæmic condition of the blood, which, however, is found along with the allied form of myeloid growth known as chloroma.

Myoma.—Myomas are of two varieties, **Leiomyoma** and **Rhabdomyoma,** consisting of unstriped and striped muscle-fibres respectively, the latter being very rare, occurring mostly as congenital tumours, *e.g.* in the kidney and heart. Striped muscle may also be found in some teratomatous tumours.

The **Leiomyoma,** on the other hand, is one of the commonest of tumours, forming rounded and often encapsuled growths, the cells of which are long and fusiform, and contain a rod-like nucleus. These cells are grouped together into interlacing bundles and whorls, with a varying admixture of fibrous tissue. The tumours themselves are not very vascular, but vessels of considerable size are often found in the capsule. Myomas frequently occur in the uterus, occasionally in the prostate, and more rarely in the walls of the alimentary canal or in the ovary. All intermediate admixtures of myoma and fibroma are found (**fibromyoma**). Secondary changes sometimes develop in myomas, *e.g.* mucoid, hyaline, necrosis, calcification, ulceration with profuse hæmorrhage, and possibly consequent inflammation, whilst sarcomatous metaplasia may occasionally supervene.

Gliomas are tumours arising from the neuroglia of the brain and spinal cord, and occasionally in the retina. Twenty varieties of cell-types have been described by Bailey and Cushing as occurring in the central nervous system during its normal development—nerve-cells, glia-cells, and the cells from which they arise or to which they give origin; and some fourteen—subsequently reduced to ten—varieties of tumours arising from these, many of them gliomatous. Though such highly complex classifications are of scientific interest, they would be out of place here, and there is now a tendency to simplify them for practical clinical use. Further reference is made to some of the more important members of the glioma group in Chapter XXVII. Such tumours vary from simple to very actively proliferating locally malignant and cellular growths. They consist of cells (which may be round, spider-shaped, or spindle-shaped) and of fibres; these occur in varying proportions in different cases, giving rise to the harder and softer varieties. Their colour often closely resembles that of the brain-tissue itself, and there may be little or no sharp line of distinction between the tumour and the surrounding tissue. They vary greatly in rapidity of growth and in vascularity, and, though often locally

malignant and infiltrating widely, seldom give rise to metastases. Various secondary changes such as degeneration, necrosis, and hæmorrhage are common, especially in the more malignant forms. An important point in connection with this series of tumour is that some of them, although histologically of 'primitive' cell-type, *e.g.* the medullo-blastoma, are comparatively amenable to radio-therapy.

Neuroma.—True Neuroma, Neuroblastoma, or **Ganglioneuroma** is rare, comparatively few undoubted cases being on record. It consists of a mass of newly-formed ganglion-cells and nerve-fibres, which may be myelinated or not. It affects especially children or young people, and usually involves the sympathetic system or the suprarenal medulla. The tumours may attain considerable dimensions, are often multiple, and may be soft or firm. They are insensitive and innocent, and may be freely removed if necessary.

Neurofibromas (False Neuromas or **Perineural Fibroblastomas),** developing in connection with the sheaths of nerves, are in reality fibromatous tumours, but may for convenience be described here under three headings:

1. **Localized Neurofibroma.**—This may project from one side of the nerve, but more frequently the nerve-fibres are spread out over it. It may be moved more freely at right angles to the axis of the nerve than in the direction of its course. When developing from a small subcutaneous twig, it has been termed a 'painful subcutaneous nodule,' and gives rise to intense radiating neuralgic pain, especially when compressed or irritated, or when exposed to cold. The single false neuroma may also grow from one of the larger mixed nerves ('trunk neuroma'), and is usually less painful.

One important site of such neurofibroma is the eighth or acoustic nerve, at the cerebello-pontine angle, but when bilateral, they form part of the more generalized condition of neurofibromatosis described below. Apart from the latter, single and occasionally several neurofibromatous tumours may arise from spinal nerve-roots. These may lie wholly within the spinal canal and may, as they grow, gradually produce compression of the cord; or they may develop in the nerve as it lies in the intervertebral foramen. As the tumour develops, the portions on either side of the narrow passage (which itself may also undergo some degree of expansion) grow larger and produce the so-called 'dumb-bell tumour.'

A growth on a purely motor nerve, though sensitive, is not associated with radiation of pain. These tumours may sometimes undergo mucoid degeneration, and, as in such tumours elsewhere, all stages between simple and malignant forms, *i.e.* sarcomas, may be found. It is uncommon for tumours of this type to cause complete paralysis or anæsthesia, unless they are of a malignant nature. They are not rare in the brachial plexus, in which case Raynaud's disease may be simulated. They occur most frequently in healthy adults, and in women a little more commonly than in men.

Treatment.—The tumour, if painful, should be removed, care being taken, if possible, not to interfere with the continuity of the nerve-fibrillæ, the dissection of the sheath being made in the long axis. If

this cannot be accomplished, the nerve must be divided, the growth removed, and if possible the ends then sutured together. In removing a painful subcutaneous nodule upon an unimportant sensory twig, it is unnecessary to endeavour to save the nerve.

The malignant 'pseudo-neuroma,' as already stated, is sarcomatous in character, and develops at first in the sheath of the nerve; spreading longitudinally, but subsequently involves the tissues around. Clinically, it presents at first the phenomena of a simple growth, but its course is more rapid and painful, and if involving a motor nerve, paralysis is induced. The main nerve-trunks are usually affected, and it may be possible to treat the case by excision or, failing this, by amputation.

2. **Generalized Neurofibromatosis (von Recklinghausen's Disease).** —This consists of nodular thickenings of the nerve-sheaths, causing multiple spindle-shaped or spherical tumours, or a generalized enlargement. The growths may be encapsuled and limited, or not; they may be few in number, or hundreds may be present, and they are usually whitish and firm in texture. Any part of the peripheral nervous system may be affected, including the *sympathetics*, but the disease is most common in connection with the *cranial nerves* and the *large plexuses of the trunk*; sometimes, when *both* acoustic nerves are involved, *i.e.* bilateral cerebello-pontine angle tumours are present, the case will usually be found to be an example of this disease. The actual symptoms are sometimes very slight, but the tumours may be sensitive to pressure, and some of them, more exposed than the others, may be extremely tender. Motor phenomena are rare, and paralysis is due usually to involvement of the nerve-roots in the spinal canal, or to the supervention of sarcoma, which is a not uncommon termination. Multiple meningiomatous tumours (p. 224) and occasionally gliomas are sometimes associated with generalized neuro-fibromatosis, as well as gliosis around the central canal of the spinal cord, sometimes accompanied by the development of syringomyelic cavities and other rarer lesions. The disease may start at any time during life, and, although progressing slowly, sooner or later terminates fatally. No known treatment is of any avail, but should any particular tumour become large and tender, it may be removed.

In this affection one not unfrequently observes the development of numerous fibrous growths of the skin, similar to what we have already described as *molluscum fibrosum.* On microscopical examination of specimens stained by Weigert's method, the presence of nerve-fibrils may be demonstrated in these growths, showing that they are really neuro-fibromatous in origin. So excessive does this overgrowth occasionally become that a form of *pseudo-elephantiasis* is produced, *e.g.* the irregular hyperplasia of the scalp-tissues, known as a pachydermatocele. The association of molluscous tumours with neurofibromatous changes in the nerves and cutaneous pigmentation was described by von Recklinghausen in 1882 (Fig. 73).

A **Plexiform Neurofibroma** is a special modification of this process, occurring congenitally or in young people, and usually involving the trigeminal or superficial cervical nerves. It may be associated with

the generalized form of the disease described above, but the overgrowth is of a softer, more gelatinous, myxo-fibromatous type, and the resulting tumour consists of a plexus of thickened, tortuous strands, of soft consistence, held together by loose connective tissue, but easily separable into their constituent elements, which are of a nodulated character, so that the dissected mass looks 'not unlike grains of boiled tapioca on a string' (Alexis Thomson). The plexiform neuroma is usually subcutaneous, but may dip deeply between and into the substance of muscles. When limited in extent, the growth may be dissected out, and this is usually required for cosmetic purposes. The

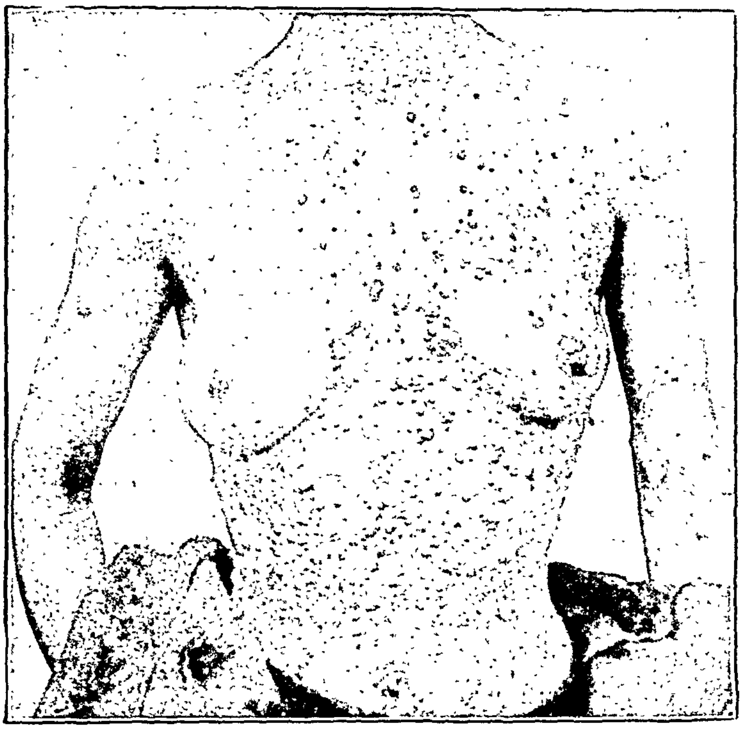


FIG. 73.—MULTIPLE MOLLUSCOUS TUMOURS AND PIGMENTATION OF SKIN IN A CASE OF VON RECKLINGHAUSEN'S DISEASE.

final prognosis is rather better than in the generalized form, as secondary sarcomatous changes are rare.

3. The bulb formed upon the end of the proximal segment of a nerve after its division is sometimes, though inaccurately, termed a 'neuroma' (**Traumatic** or **amputation 'Neuroma'**). It consists of a bulb-like mass of fibro-cicatricial tissue, amongst which there have developed in irregular interlacing whorls numbers of proliferating axis-cylinders.

(2) Malignant or Atypical Pulp-tumours ('Sarcomas').

Sarcoma (a flesh-like tumour; Greek, σάρξ, flesh).—A sarcoma is a malignant tumour which consists of a parenchyma, formed of cells which have taken on the power of continued and apparently limitless

growth, and of a varying amount of supporting network or stroma. It is characteristic of the sarcomas that these two elements are intimately mingled together, each parenchyma-cell being separated from its neighbours by delicate fibrillæ of the stroma; in the carcinomas the parenchyma cells tend to occur in masses or islands which are enclosed by the stroma. Sarcomas have in the past usually been regarded as being of **mesoblastic** origin only, the parenchyma-cells resembling those from which the connective tissues are formed in the embryo both in shape and in their capacity for continued growth; hence they are often referred to as 'embryonic connective-tissue cells.' Analogous malignant tumours may, however, arise from the pulp-tissues derived from **epiblast** (neuroglia in all its varieties) and **hypoblast** (the notochord and its remnants).

A sarcoma may at first appear to be well defined or even encapsulated; but many forms from the first, and all later on, infiltrate, destroy and replace the surrounding tissues. The **blood-supply** is very abundant, and, indeed, may be so free as to cause the tumour to pulsate. The blood-vessels consist of spaces or clefts within the tumour substance, and are lined by the most delicate endothelium or merely by the tumour-cells; the arteries and veins in the neighbourhood are often dilated. Interstitial hæmorrhage is frequent, owing to the imperfect nature of the vessel-walls, and pseudo-cystic cavities may in this way be produced. **Dissemination** is usually dependent on the relation of the tumour to these imperfect blood-spaces and veins. As already stated, the veins communicate with such blood-spaces; into and along these the actively proliferating sarcomatous cells may burrow, until the apex of this intravascular growth projects into the lumen of a vessel in which the blood is freely circulating. It may be detached by some slight mechanical injury, and is then carried away as a malignant embolus; if a large portion is set free, as in sarcoma of the kidney, it may lodge in the right side of the heart, or in the lungs, and cause a fatal result. Smaller emboli —perhaps even a single tumour-cell or small group of these—are either detained in the lungs, or pass through into the general circulation, giving rise to secondary growths wherever they are arrested; general visceral implication is often secondary to the pulmonary growths. Occasionally dissemination by way of the lymph-nodes occurs, especially in a lympho-sarcoma and sarcomas of the tonsil, testis, and thyroid body, and this in spite of the fact that lymphatics are not known to be present in sarcomas.

Some of the forms of sarcoma described below have a tendency to develop, usually only very imperfectly, into tissues which bear a resemblance to the normal connective tissues, and tumours in which this process has taken place often receive special names, *e.g.* fibro-sarcoma, in which the cells tend to become organized into fibrous tissue; osteosarcoma, in which they tend to develop into bone; chondro-sarcoma, liposarcoma, lymphosarcoma, etc. The metastatic growths usually resemble closely the parent tumour; thus masses of osteoid tissue may develop in the lungs when the primary growth is an osteo-sarcoma.

Degenerative changes of a fatty or mucoid type and necrosis are also apt to occur in the older portions of a sarcoma, giving rise to the production of pseudo-cystic cavities. Hæmorrhage is common in the softer varieties, and calcification may sometimes occur in the more slow-growing forms.

On naked-eye examination, a sarcoma on section presents a more or less homogeneous appearance, the colour varying with the amount of the blood-supply, from a greyish-white in the fibro-sarcoma to a deep red in the small round-celled. Its consistency, whether hard or soft, depends on the amount of stroma present; the more malignant are usually soft and may pulsate visibly; the more slow-growing are often firmer. The degree of malignancy varies considerably, some forms being almost 'benign,' or, at any rate, infiltrating only slowly and locally, whilst others are exceedingly malignant in nature. Such **malignancy** may take the form of rapid local **infiltration** and destruction of neighbouring tissues; or of **metastases** at a distance; or a **combination** of these two processes.

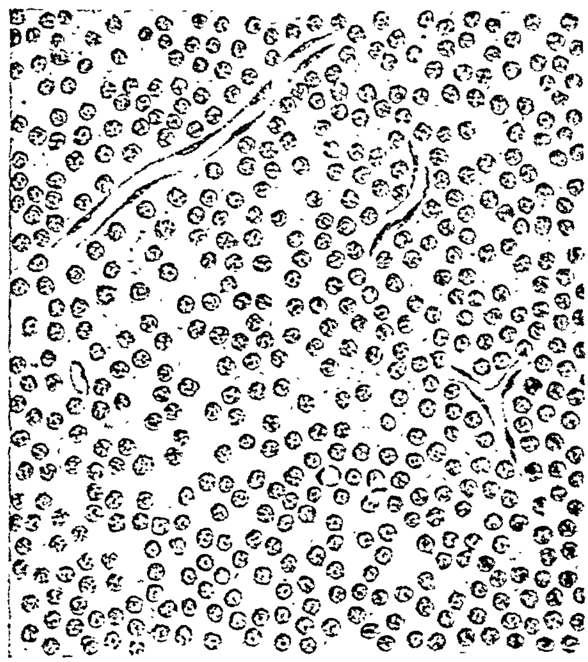


FIG. 74.—SMALL ROUND-CELLED SARCOMA, SHOWING GREAT CELLULARITY OF THE TUMOUR, AND IMPERFECT STRUCTURE OF THE VESSELS. (× 300.)

Sarcomas are, for convenience, divided into the following groups, depending on the size, shape, arrangement, and character of the constituent cells:

(1) **Round-celled Sarcomas** (Fig. 74) usually consist of a mass of **small round cells,** each containing a very definite circular or oval nucleus; the intercellular substance is scanty, and often homogeneous in character. The mass is very vascular, and may even pulsate; it is soft, like granulation-tissue, and usually grows rapidly. It is extremely malignant, infiltrating surrounding parts, and early giving rise to secondary deposits; the lymph-nodes are not infrequently affected in this variety. The small size of the cells is attributed by some to their anaplastic character or so-called 'reversion to embryonic type,' leading to their rapid multiplication before attaining to a larger size. Any part of the body may be involved, and this variety of tumour may occur at any age. **Lymphosarcoma** is a very primitive variety of this type (Fig. 75), in which the intercellular substance is extremely scanty and of a delicate reticular nature, corresponding to the retiform

tissue occurring in lymph-nodes. They grow rapidly and are exceedingly malignant, originating usually in lymph-nodes, the thymus or in the lymphoid tissue of mucous membranes; and are disseminated by means of the lymphatics. For the clinical characters of lymphosarcomas, see Chapter XIV., p. 382.

The **large round-celled** sarcoma is a less common variety made up of larger cells, which contain one or more large oval nuclei with abundant cytoplasm and a well-marked stroma interspersed between the cells. It occurs in the same positions as the small-celled variety, but is rather less malignant.

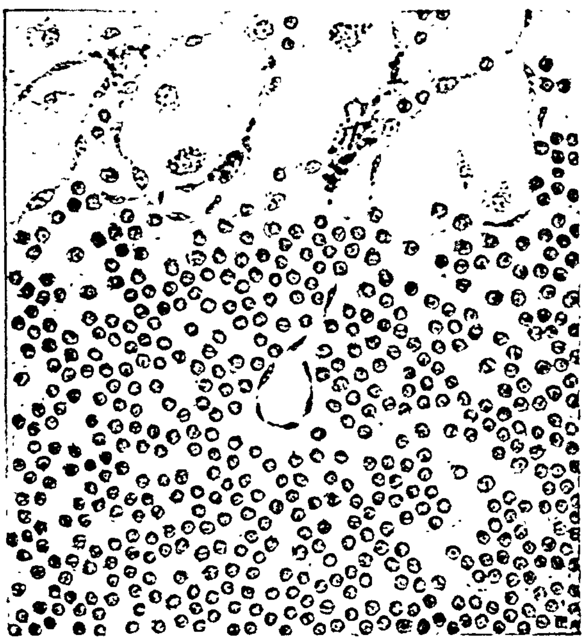


FIG. 75.—LYMPHOSARCOMA, SECONDARY IN LUNG, SHOWING ACTIVE INVASION AND REPLACEMENT OF THE LUNG-TISSUE, SOME SURVIVING ALVEOLI (WITH CARBON PIGMENT IN THEIR WALLS) BEING SHOWN AT THE UPPER PART. (× 300.)

(2) **Spindle-celled Sarcomas** (Fig. 76) consist of large or small spindle cells, which are often arranged in a somewhat fasciculated manner with a varying amount of intercellular substance.

When consisting of **small cells,** these tumours grow rapidly, and are firmer and less succulent than the round-celled variety. They may originate in any part of the body, but more especially from aponeuroses, fasciæ, tendons, etc., constituting localized growths, which may at first be fairly well defined, but later invade and infiltrate surrounding parts. When growing rapidly, the cells become less fusiform in shape, and may even approach to the round cell in character, after passing through a stage known as the oval or '**oat-celled' sarcoma.** A few giant-cells are often seen in these cases. Such small spindle-celled tumours are usually very malignant.

In some few cases the cells develop into rather more fully-formed fibrous tissue, and the tumour then closely resembles a simple fibroma. These tumours are known as **fibrosarcomas** ('recurrent fibroid' tumours of Paget), and are not uncommon in the subcutaneous tissues, arising, it may be, from nerve-sheaths (see Fig. 77). They rarely form metastases, but, after even apparently complete surgical 'removal,' tend to reappear, perhaps not until after an interval of two or three years. After each operation, they usually 'recur' more rapidly; and show signs of progressively greater malignancy, until,

after perhaps being removed a dozen times, they 'recur' with all the characters of a typical spindle-celled sarcoma.

The **large spindle-celled** sarcomas are softer and of a deeper colour than the above forms. They grow from the fibrous tissues, and not uncommonly from the viscera.

(3) **Mixed-celled Sarcomas** are of not unfrequent occurrence, varying admixtures of two or more of the above types being present in the same tumour. Ill-differentiated masses of protoplasm containing two or three nuclei are present and resemble giant-cells.

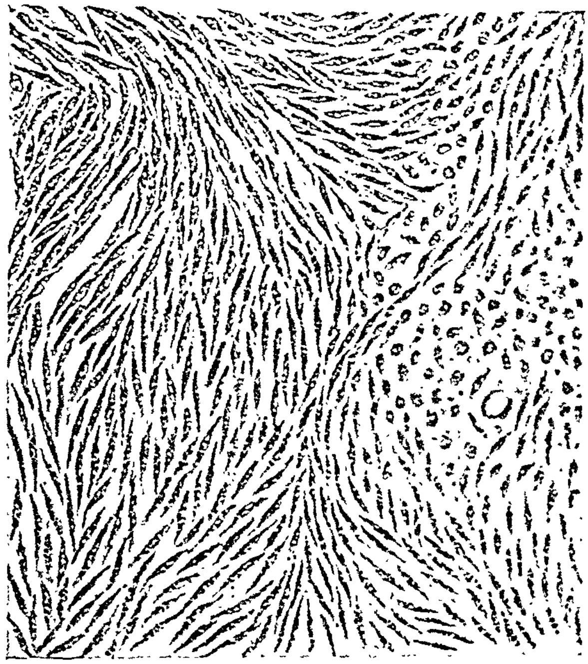


FIG. 76.—SMALL SPINDLE-CELLED SARCOMA. Some of the fibres run in longitudinal bundles; others are cut transversely. Intercellular material is scanty and the vessels imperfect. (× 300.)

The **Treatment** of sarcoma consists in its **removal,** if practicable, as early and completely as possible. Even in cases where the tumour appears to be encapsuled, recurrence is very likely to follow unless the capsule is also taken away, and a considerable margin of tissue beyond it. Where the growth is more diffuse, the only hope lies in cutting widely, so as to get beyond its furthest limits, and it may be advisable to remove the skin over it and the lymphatic area leading from it; the prognosis of such cases is very grave.

In cases where, owing to the position of the growth or its extent, complete removal is impossible, a partial operation may be feasible, cutting away part of the tumour with a diathermic cautery, and trusting to **radio-therapy** (p. 305) to destroy the remainder, employing either X-rays or radium. In the former case one or two pastille doses over different areas are given twice a week at a sitting. In the latter small doses of radium may be buried in the tumour substance for six to eight days. Lead therapy, and the use of selenium compounds, in combination with or followed by irradiation, are still in their experimental stage.

In hopelessly **inoperable** cases analogous measures have been employed as described later for the similar stage of cancer (*vide* p. 310). Cures have been recorded from the use of Coley's fluid, which consists of a sterilized culture of the *Streptococcus pyogenes* of erysipelas and *Bacillus prodigiosus* in bouillon. This fluid is intensely toxic, and the injections, commencing with doses of half a minim (0·03 c.c.), are

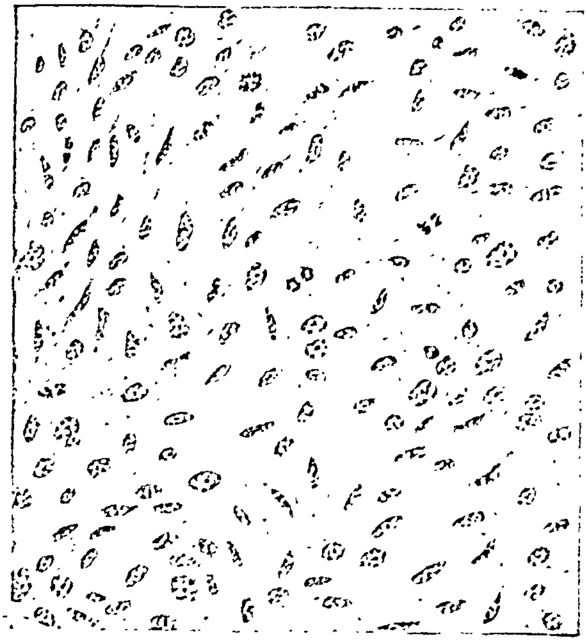


FIG 77.—FIBROSARCOMA—THE SO-CALLED 'RECURRENT FIBROID.'

The specimen from which this preparation was made was the third 'recurrence' after operation. In histological structure it is intermediate between the soft fibroma (Fig. 63) and the spindle-celled sarcoma (Fig. 76). (× 300.)

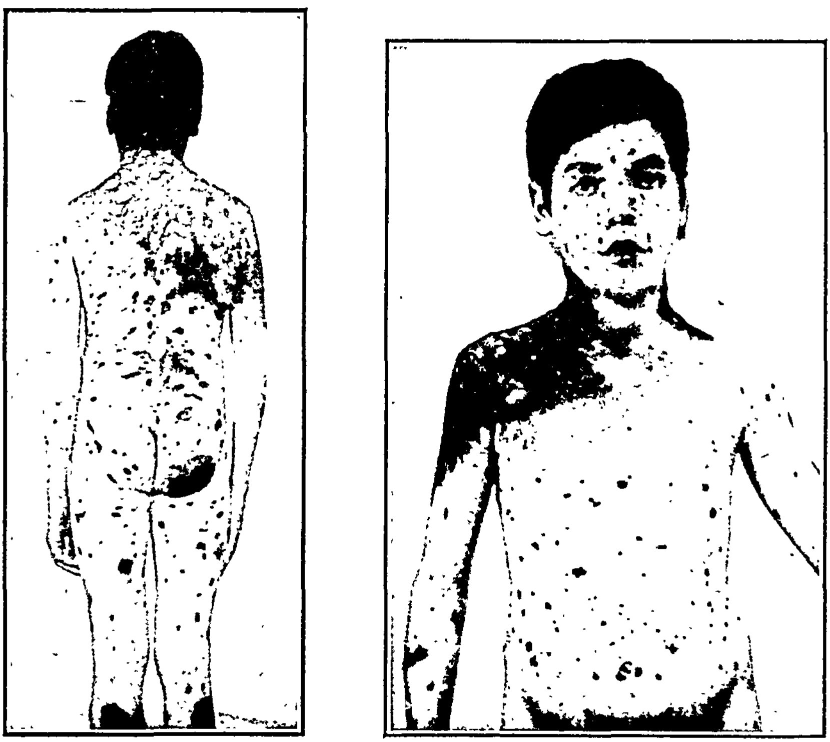


FIG. 78.—MULTIPLE MELANOMAS OF THE SKIN IN A BOY AGED EIGHT YEARS.

gradually increased to 7 or 8 minims (0·45 or 0·5 c.c.) or more; severe reaction usually follows, and one should aim at obtaining two or three such effects each week. The fluid is introduced partly into or around the tumour and partly elsewhere. If it is going to do any good, the improvement is manifest in a few days, and as the course of treatment proceeds the growth gradually dwindles. The patient is treated for three or four weeks at a time, and then given a rest, as the repeated reactions are very trying, and to persist in this treatment requires much pluck and patience. The results reported from America have hitherto been more encouraging than those in this country.

FIG. 79.—ALVEOLAR TYPE OF MALIGNANT MELANOMA, SHOWING THE ACTIVELY GROWING SPINDLE-SHAPED AND IRREGULAR CELLS, AND THE OFTEN PATCHY DISTRIBUTION OF THE MELANIN-PIGMENT.

This tumour was a secondary growth arising from a pigmented mole on the skin. (× 300.)

Melanomas are pigmented tumours, of which the **simple** types are represented by the congenital pigmented nævi or moles and warts of the skin (Fig. 78). From these, and also from those portions of the body which are naturally pigmented, *e.g.* the uveal tract of the eye (choroid and iris and the rete mucosum layer of the skin), and occasionally from the meninges or from the rectum, **malignant melanomas** may arise. The exact origin, epithelial or mesoblastic, of the chromatophores or pigmented cells of these tumours has not been fully settled, but the tumours are probably melano-carcinomas. The main type of cell present may be squamous, spheroidal or spindle-celled, and it is possible to recognize three main types of growth: the *papillary*, in which there is a loose papillary formation and the cells are mostly squamous; the *alveolar* type, in which the growth has an alveolar structure and the cells are either spheroidal or spindle-shaped (Fig. 79); the *diffuse* type, in which the growth develops like a sarcoma and the cells are mostly spindle-celled. They constitute perhaps the most malignant type of neoplasm on account of their tendency to give rise at an early stage to metastases in any tissue or organ of the body. Those growing from the eye are usually composed of spindle-cells, which contain granules of melanin; these choroidal tumours have a tendency to form secondary deposits, especially in

the liver. The pigment-granules in this form are very unevenly distributed, some lying in the stroma between the cells, whilst others are contained in the cells (see Fig. 79); some portions of the primary tumour are often free from pigment, and some of the secondary growths are colourless, whilst adjacent growths may be a very dark brownish-black. Apart from the tumours, the melanin-pigment may be deposited in the skin of the patient (melanosis) or may be excreted in the urine (melanuria).

If the primary tumour is not removed very early, the nearest lymph-nodes are soon affected, and secondary metastases follow, particularly in the liver. The original tumour is often not very large, and the secondary deposits are frequently characterized by their number rather than by their size, perhaps scarcely an organ or tissue in the body escaping attack.

II. Rind-tumours derived from Covering and Lining Tissues.

(1) Simple or Typical.

The various tumours grouped under this heading are composed mainly of epithelium or other covering or lining cells, combined with a varying admixture of connective tissue. They are derived from pre-existing epithelial or other analogous structures, and vary in the arrangement and character of the cells with the site of origin. For convenience of description, we may take first the simple tumours arising from epithelial tissues, the papilloma and adenoma.

FIG. 80.—SECTION OF A WARTY PAPILLOMA TO SHOW THE ARRANGEMENT OF THE EPITHELIUM. Hypertrophied papillæ, over which is heaped up a mass of thickened keratinized cuticle. There is no invasion of the subcutaneous tissues, as in an epithelioma. (× 10.)

Papilloma.—A papilloma consists of a central core of connective tissue, blood-vessels, and lymphatics covered by epithelium which may be squamous, cuboidal, or columnar. Papillomas may be considered according to the type of their epithelial covering.

(1) Those covered by **squamous** epithelium occur in the skin, lips and mouth, larynx, vagina, anus, etc., and consist of projecting papillæ, undergoing proliferation and frequently branching to form secondary papillæ. If the epithelium undergoes keratinization, as in common warts,

the latter become hard, and may constitute horn-like outgrowths (Fig. 80). When such outgrowths occur in moist situations, *e.g.* between the toes, on the prepuce, or growing from mucous membranes (except that covering the vocal cords), this formation of horny substance is usually very imperfect, and the papillomas remain soft. Many such warty outgrowths are in reality of infective origin, and not true tumours, *e.g.* venereal warts, condylomas, and mucous patches. There are also reasons for suspecting that the common cutaneous wart may be infective and due to a micro-organism. Wart-like tumours may develop in connection with the later stages of acute X-ray burns and in chronic radio-dermatitis. In the latter condition and also in other forms of papilloma, especially if subject to continued irritation, malignant metaplasia and development into squamous epithelioma may supervene, a change characterized clinically by the base becoming infiltrated.

The papillomas which develop from the mucous membrane of the bladder or pelvis of the kidney are covered by **transitional** epithelium from a few up to many cells deep, arranged in fimbriated tufts containing a delicate vascular connective-tissue core. Fragments of such tumours readily become detached, with resulting hæmorrhage, sometimes considerable in amount. It is not always possible from its histology alone to judge whether a particular villous tumour of the bladder is simple or malignant, and, though often at first apparently benign, such tumours are apt to develop local malignancy, gradually infiltrating the surrounding tissues, and later perhaps becoming even actively invasive; whilst in other instances definite and perhaps marked malignant characters may manifest early in the course of their development.

(2) Papillomas covered by **cuboidal** or **spheroidal** epithelium occur in glandular structures, especially in the breast, kidney, etc.

(3) Papillomas covered by **columnar** epithelium are sometimes found projecting into cystic cavities in tumours of other types—for example, in the proliferous ovarian cysts and in duct-carcinoma of the breast, as also into dilatations of other ducts. Papillomatous projections are also common in bronchial carcinomas, and especially in the metastatic cystic tumours arising from these, *e.g.* in the mediastinal lymph-nodes, brain, etc. The 'papillomas' of the intestine are usually either adenomas or fibromas which have become polypoid.

Adenomas are tumours arising in connection with secreting glands, and such growths not unfrequently tend in varying degree to reproduce the structure of the particular type of organ from which they arise (Fig. 81). They differ from these, however, in that they do not produce the normal secretion, the alveoli or other characteristic type of gland-structure being often very imperfectly reproduced. The epithelium, whether spheroidal, cuboidal, or columnar in shape, does not pass beyond the basement-membrane into the connective tissue, and by this lack of infiltration such simple adenomas are distinguished from cancerous tumours. A variable amount of supporting connective tissue is always present, and may be normal in texture, or may manifest various modifications. When the stroma is greatly increased,

the resulting mass is termed a *fibro-adenoma*, which may be hard or soft, depending on the amount and toughness of the fibrous tissue present (Fig. 81). *Columnar-celled adenomas* are found chiefly in the intestinal tract, but also occur in those organs lined by columnar epithelium, such as the ovary, uterus, bronchus, and gall-bladder. *Spheroidal-celled* adenomas are met with most commonly in the breast, but also occur in the pituitary, adrenal, and prostate. *Cubicle-celled* adenomas are found in the thyroid gland. Adenomas are single or multiple, and usually encapsuled, and may perhaps be connected with the original gland merely by a pedicle, through which the vessels enter. Others, when growing from mucous membranes, sometimes become pedunculated, as in the so-called 'rectal polyp' when this is not merely hæmorrhoidal in origin. The alveoli in some cases become distended with effusion—perhaps mucoid in character—giving rise to a cystadenoma, and sometimes portions of the tumour project into these, constituting an intracystic papillomatous growth. In such adenomatous tumours, carcinomatous metaplasia may supervene, especially in the breast. When of large size, they may press upon and perhaps interfere with the function of important structures. Any glandular organ may be the seat of an adenoma, *e.g.* the breast, thyroid, prostate, testis, etc. These growths are also found as congenital tumours in connection with the thyroid, post-anal gut, and possibly the kidney.

FIG. 81.—HARD FIBRO-ADENOMA OF THE BREAST. (× 30.)

Angioma.—A **Hæmangioma** is a tumour of which the essential constituents are blood-vessels or blood-spaces, with their endothelial lining, for a description of which see p. 367. A **Lymphangioma** is the analogous tumour consisting of the corresponding lymphatic structures (see p. 368).

(2) Malignant or Atypical.

Cancer or Carcinoma.—The malignant forms of epithelial new growth are known as the 'cancers' or 'carcinomas.' Any epithelial surface or organ may be affected, but cancer is seen most frequently in parts which are exposed to injury or chronic irritation. In the **male,** the stomach is the organ most often affected, and then follow in order

the intestines, tongue, and mouth, etc.; a large proportion of all cancers in the male sex affects the intestinal canal. In the **female,** cancer of the uterus, ovaries, and breast accounts for nearly eighty per cent. of all cases of the disease. In both sexes cases of cancer of the lung (bronchial carcinoma) are now said to amount to 5 or 10, and in some series even 15, per cent. of post-mortem examinations on cases of malignant disease. Carcinoma is not very common in early life, but increases in frequency after the age of thirty, and reaches its maximum incidence between forty and fifty-five years of age, but, according to the statistics of the Imperial Cancer Research Fund, it is thirty times more frequent as an actual cause of death at seventy-five than at thirty-five.

The essential character of a cancerous growth consists in an unlimited multiplication of the epithelial cells of the organ or tissue attacked. These cells are arranged in groups or masses, and usually retain little resemblance to the structure of the normal organ or tissue from which they arise. The epithelial cells of such malignant tumours are anaplastic, losing control of their more specialized structural characters and physiological powers, but retaining in excessive degree those of growth and subdivision. In individual tumours, the cells often differ greatly among themselves in size, character of nuclei, staining properties, etc., and in rapidly-growing carcinomas numerous mitoses may be seen. In general, the greater the anaplasia, the greater the malignancy. Bröder has attempted to classify the degree of malignancy according to the type of cell present and its arrangement. In his opinion all types of malignant growths fit into one of four categories, Group I. being the least, and Group IV. the most, malignant. Thus in the case of an epithelioma those cases which showed cell-nest formation and central keratinization would be classed in Group I. Those cases in which cell-nests were present but keratinization was absent belonged to Group II. In Group III. keratinization and cell-nest formation were both absent, but prickle-cell formation remained a feature. In Group IV., however, the growth was anaplastic and prickle cells were absent. The drawback to this classification is that pure groups do not often occur; furthermore, experience has shown that, apart from the anaplastic type of growth, the microscopical appearance is by no means an accurate guide to the degree of malignancy present or a guide to its reaction to treatment. There is also an alteration of the mutual relations between the epithelial cells and the connective tissue of the part. The former do not remain limited by normal basement-membranes and other mesoblastic elements, but penetrate these, producing **infiltration** of the surrounding or subjacent tissues, as a rule following the lines of least resistance, and extending especially along the lymph-spaces, though a resistant tissue such as bone may be infiltrated and destroyed. There is thus no longer a sharp and definite line of demarcation between the epithelial and connective-tissue portions of the tumour (as in innocent growths), but the two are inextricably blended.

Dissemination of Carcinoma in the body takes place in one of four ways: (1) By *direct extension* as the growth increases in size and in-

filtrates the surrounding tissues. (2) By *lymphatic spread*, which forms the most important method of diffusion of the growth. It may take place either by (*a*) *embolism*, in which a few cancer cells become disconnected from the primary growth and get carried along with the lymph-stream usually to the nearest lymph-gland; or (*b*) by *permeation*, in which the cells grow along the lumen of a lymphatic vessel as a solid chain. Spread by emboli takes place in the direction of the lymph-flow, but the permeation process spreads in all directions so that the surrounding lymph-vessels become choked, giving rise to a non-pitting type of œdema. (3) By the *blood-stream*. This method takes place when the wall of a vessel becomes invaded by the growth. It is much less common than the other two methods, but is usually present in all advanced cases. (4) By *direct implantation* from one epithelial surface to another. This is seen most often in connection with epithelioma of the vulva and of the large bowel, or less directly in the pleural or peritoneal cavities in which transcœlomic implantation may take place.

FIG. 28.—SQUAMOUS EPITHELIOMA OF THE FINGER.

Marked changes occur in the connective tissues around the cancer; they are irritated by the growth, and become infiltrated with 'small round cells' and plasma-cells, and undergo a greater or less degree of organization, leading to the development of a stroma of variable density and vascularity around the invading epithelial cells. In chronic cases the stroma is usually fibrocicatricial in type and contains few blood-vessels; in the more actively growing parts and in acute cases the stroma is comparatively scanty, more cellular and vascular. When ulceration has occurred, or sometimes in and around areas of necrosis, polymorphonuclear leucocytes are usually abundant, and other inflammatory manifestations may be seen; pyogenic bacteria may invade the growth.

Cancerous tumours are not necessarily tender to the touch, but a considerable degree of pain, usually of a neuralgic type, is often present, especially in the harder forms when the tissues are dragged upon by the contracting stroma.

The enlargement of the neighbouring lymph-nodes is usually an early and important sign of malignant spread, but it must be remembered that, when the primary growth has a dirty ulcerating surface, the enlargement may be due in part to the absorption of bacteria and toxins, and treatment directed to cleansing the surface of the sore may in such cases lead to a considerable reduction of this enlargement.

Varieties.—Broadly speaking, cancers may be classified as (1) squamous-celled epithelioma, (2) columnar-celled, and (3) spheroidal-celled cancer, according to the type of cell of which they are mainly composed. The term 'colloid cancer' is used to indicate a degenerative change occurring in some forms.

1. **Squamous Epithelioma** (*syn.:* **Squamous-Celled Carcinoma: Acanthoma**).—By this term is meant a cancerous tumour growing from skin (Fig. 82) or from those portions of mucous membrane which are covered with squamous epithelium. They also arise occasionally from such structures as remnants of the thyroglossal duct or Hassall's corpuscles in the thymus.

Squamous epithelioma is most liable to occur in middle-aged or elderly individuals, but occasionally earlier in life. Any part of the skin may be the site of this tumour, as also the mucous membrane of the mouth, pharynx, larynx, and œsophagus, and that lining portions of the genito-urinary tract. It frequently follows upon some long-continued irritation, as on the lip or tongue, or cervix uteri, whilst upon the penis it is usually associated with a long foreskin. Chronic irritation of old scars may also be followed by such malignant change, especially if they become ulcerated; and the disease may supervene upon intractable lupus, or in the mouth upon a patch of syphilitic leucoplakia.

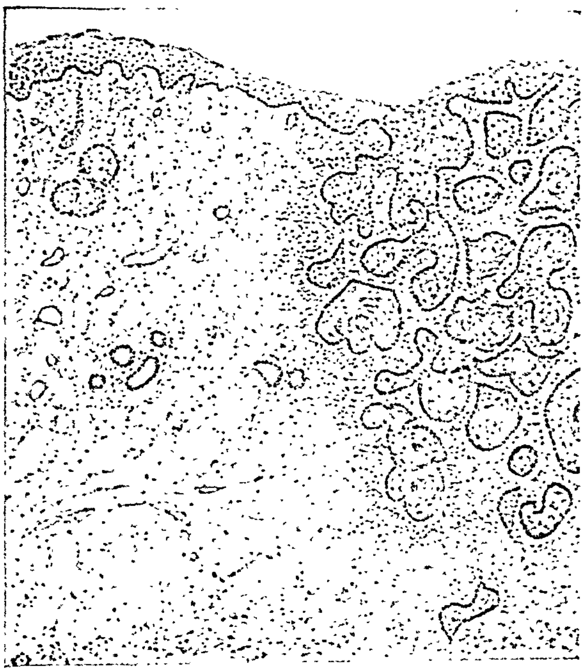


FIG. 83.—SQUAMOUS EPITHELIOMA.

Very low-power view to show the invasion of the deeper tissues by the proliferating malignant surface cells and formation of cell-nests. (× 30.)

Clinically, epithelioma may be looked upon as a **malignant wart,** which, however, not only grows outwards from the surface, but also breaks through the basement membrane and burrows deeply into adjacent tissues (Fig. 83). Several characteristic forms are described: (*a*) The typical epithelioma which occurs as a nodular indurated mass, with hard everted edges and central ulceration, giving rise to a deep or crateriform ulcer (Fig. 84). (*b*) The destructive process may follow closely upon the new formation, leading to the appearance of a depressed sore (**malignant ulcer**) with sharply-cut edges, and resembling a rodent ulcer. (*c*) The **hypertrophic type** in which the superficial outgrowth is excessive, and the destructive

process limited, giving rise to a projecting cauliflower-like mass, which is soft and bleeds easily, constituting one form of **malignant papilloma.** (*d*) A slowly-growing form is sometimes seen, in which the fibrous stroma, produced from the connective tissue of the invaded area, just as in the analogous case of scirrhus cancer, contracts and compresses the masses of epithelial cells; the surface is indurated and wart-like, with little ulceration, whilst the base is hard, and the progress of the disease less rapid than in other forms. This is the indurated variety and is not uncommon on the lip.

Squamous epithelioma, as a rule, spreads early in its course to neighbouring lymph-nodes, and as the disease advances more distant groups of lymph-nodes also become involved. It is unusual to find this form of cancer disseminated to the internal viscera, though this may occasionally occur.

Death in cases of squamous epithelioma is due mainly to cachexia and exhaustion, unless, as is often the case, it is brought about by the intervention of some intercurrent malady, *e.g.* by septic broncho-pneumonia or hæmorrhage resulting from ulceration into the main vessels of the neck in cases involving the mouth and spreading to the cervical lymph-nodes, etc.

Fig. 84.—Typical Epitheliomatous Ulcer, showing Heaped-up Margins and Deep Central Crateriform Excavation. (College of Surgeons Museum.)

Microscopically, squamous epithelioma consists of masses of epithelial cells (Fig. 85), invading and ramifying in the subjacent tissues, and interlacing freely with each other, so as to produce an irregular network, the meshes of which are occupied by a fibro-cellular stroma and the remains of the invaded tissues. The cancer-cells are derived from the prickle-cell layer of the epidermis, hence the term '**acanthoma**' (Greek, ἄκανθα, a thorn or prickle), but in rapidly-growing cases the prickles or intercellular bridges may not be in evidence. The cells in contact with the stroma are usually regular, and resemble the basal layer of normal skin; the cells next to these are polygonal in shape, and in the deepest or more central layers may become flattened and tend to undergo imperfect keratinization. This differentiation is best seen in the 'cell-nests' which develop in the substance of the invading cell-masses; they are most common in comparatively chronic cases, and may be absent in the more rapidly-growing forms.

Rodent Ulcer or Basal-celled Carcinoma.—This important variety of tumour is fully described in the section on surgical diseases of the

skin (Chapter XVII.), and it is therefore sufficient here to refer to it comparatively briefly. The name 'Rodent Ulcer' is somewhat unfortunate, as in the earliest stage of its growth, when it is important that the diagnosis should, if possible, be made, it is neither 'rodent' nor an 'ulcer,' but a small *papule* or *nodule* over which the skin is tightly stretched, giving it a shiny burnished mother-of-pearl-like appearance, whilst only later, perhaps after several years, when this nodule has slowly extended laterally, does the skin over its centre break down and ulcerate. In this later ulcerative stage it tends slowly and progressively to invade and infiltrate the subjacent tissues, including muscle and bone; but *early diagnosis*, long before this stage is reached, may allow of successful treatment with radium, or an early excision may entirely eradicate the tumour. The exact origin of rodent ulcer and certain other closely allied epithelial tumours has been much debated, but it is sufficient for our purpose here to state that it arises in all probability from the basal or formative layer of the stratum Malpighii, or from the analogous cells of such epidermal structures as the sweat and sebaceous glands or hair-follicles. 'Cell-nest' formation and metastases to neighbouring lymph-nodes are both so exceptional in true rodent ulcer that they may be regarded as practically not occurring, though in certain rare instances tumours apparently intermediate between rodent ulcer and squamous epithelioma may occur. The common sites of origin are found in the triangular area lying between the outer margin of each orbit and the centre of the upper lip, but the general clinical characters of this tumour will be dealt with more fully in Chapter XVII.

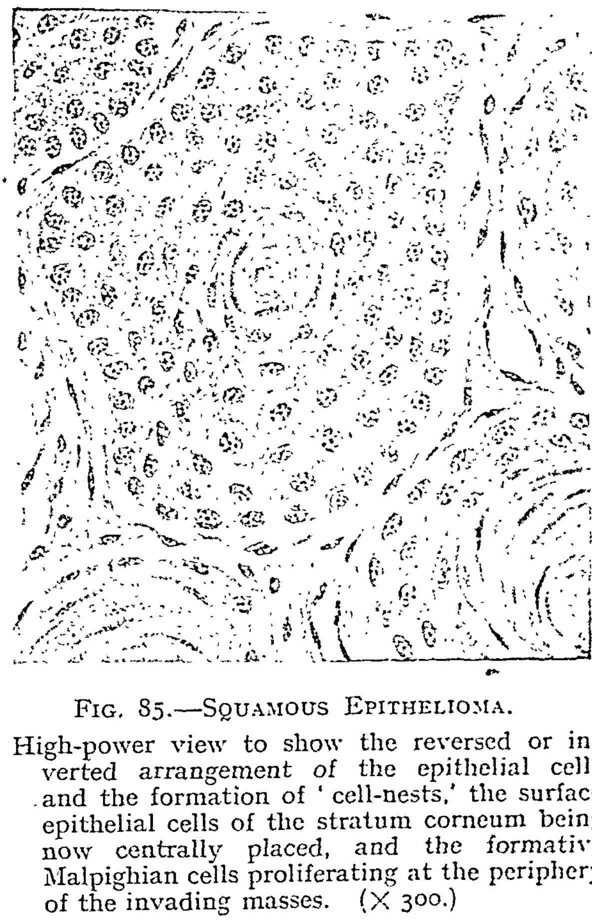


FIG. 85.—SQUAMOUS EPITHELIOMA.

High-power view to show the reversed or inverted arrangement of the epithelial cells and the formation of 'cell-nests,' the surface epithelial cells of the stratum corneum being now centrally placed, and the formative Malpighian cells proliferating at the periphery of the invading masses. (× 300.)

Microscopically, the small rounded, polyhedral or sometimes spindle-shaped epithelial cells, with relatively large nucleus and scanty cytoplasm, may be arranged in a network of intercommunicating columns or bands, or, more rarely, and perhaps where the tumour arises from

one of the epidermal glands, there may be a somewhat alveolar arrangement, in which imperfect acini may even be developed.

Chorion-epithelioma is a rare form of malignant tumour which originates in the undifferentiated protoplasm of the chorionic villi of the developing ovum. Occasionally it is found in the testicle, forming about 2 per cent. of the malignant growths of that organ, and very rarely in connection with a teratoma.

It contains three types of cells—namely, large multi-nucleated masses of protoplasm derived from the syncytial layer, small masses

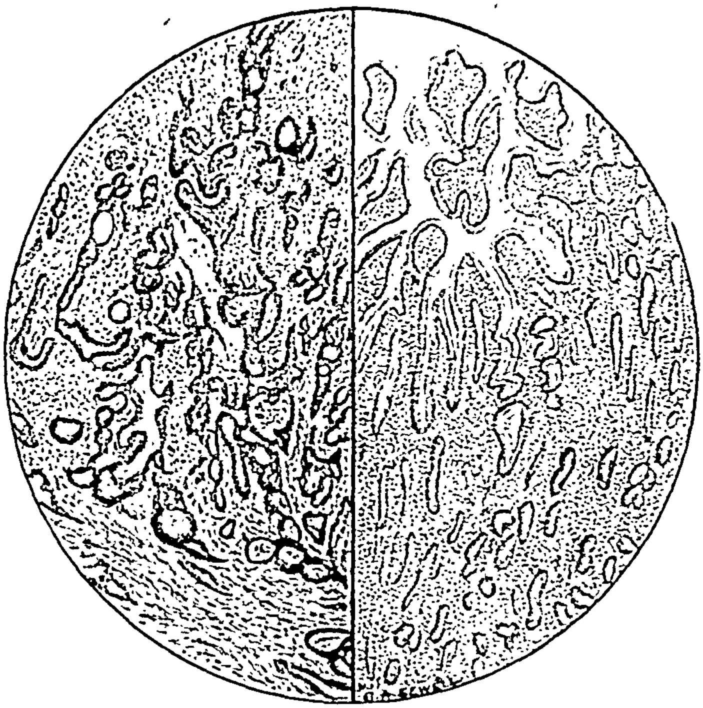


FIG. 86.—COLUMNAR CARCINOMA OF INTESTINE, COMPARED WITH NEIGHBOURING UNAFFECTED INTESTINAL MUCOUS MEMBRANE. (× 30.)

The right half is a somewhat oblique or tangential section of the normal villi of the mucous membrane, showing merely some excess of leucocytes, owing to proximity to the growth. The left half is cancerous, with irregularly-shaped glandular tubules burrowing into and infiltrating the submucosa.

similar in appearance but which are usually referred to as giant-cells and polygonal cells derived from the cells of Langhan's layer.

It is a very vascular tumour invading the uterine wall with great rapidity and giving rise to early metastases, which may, however, heal spontaneously if the primary growth is removed.

(*a*) **Columnar-celled Carcinoma** may arise from the secreting epithelium of glands, from the cells lining their ducts, or from the various component epithelial elements of mucous membranes, *e.g.* those of the alimentary canal, where they form growths which project from the surface and also penetrate deeply into the submucous and muscular coats (Fig. 86). The deep invading processes retain an imperfect alveolar arrangement, and between them is found a certain amount of

stroma. In the more chronic forms the stroma is abundant, and fibro-cicatricial in character; in the softer and more rapidly growing forms the stroma is less abundant, and fibro-cellular. The alveoli are more irregular in size and shape than those of the normal glands from which they arise, and the individual cells also show aberration from the normal type. If a large section, including the whole thickness of, say, the intestinal wall, is examined, the extension of the adenomatous tissue into and between the muscular fasciculi indicates the malignant nature of the case. Ulceration usually occurs, giving rise to a characteristic lesion, surrounded, in the more chronic forms, by indurated and everted edges. Neighbouring lymph-nodes become implicated, whilst later the disease spreads to the viscera, and may be generally disseminated. A similar type of growth may arise from the uterine mucous membrane, and occasionally from the ducts of glands, such as the liver, pancreas, or breast.

(*b*) **Spheroidal - celled Cancers** are those in which the acinar structure is lost, and the cancer-cells are found in solid groups of varying size, infiltrating through the basement-membrane and invading the surrounding tissues. The amount and character of stroma varies considerably, and, according to whether it is abundant or scanty, the tumour is hard or soft in consistence, and slow or rapid in growth. To the former type the term **Scirrhus Cancer** is applied; to the latter (from its similarity in consistence to brain-tissue), **Encephaloid.** All intermediate varieties between these two extremes occur, the same tumour not unfrequently showing considerable variation in different areas.

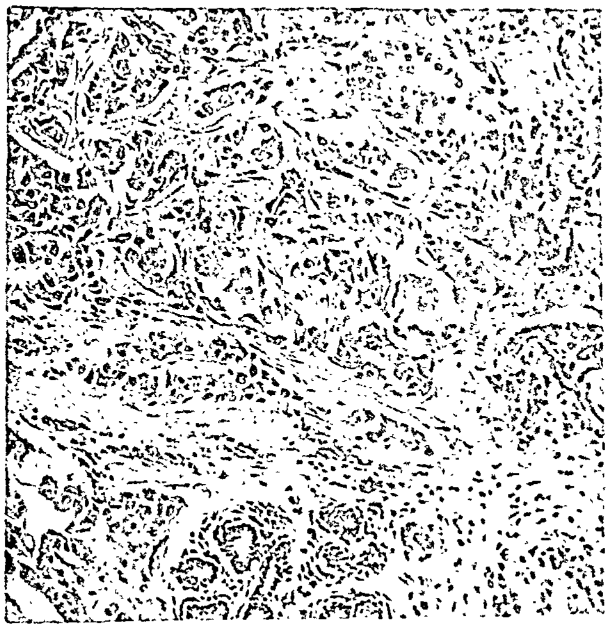


FIG. 87.—SCIRRHUS CANCER OF THE BREAST. (× 120.)

A lobule of normal breast-tissue is seen at the lower margin.

(i.) The **Hard Cancer** or **Scirrhus** form occurs most frequently in the breast, but also in the prostate, pancreas, and pyloric end of the stomach. On naked-eye examination a scirrhus tumour appears as a hard nodular mass, the limits of which are imperfectly defined. When cut across it creaks under the knife, and presents a yellowish-white surface, which becomes concave owing to contraction of the fibrous stroma. It has been compared to the section of an unripe pear or turnip, on account both of the grating sensation imparted to the knife and of its appearance.

On microscopical examination, the tumour is found to consist of the invading cancer-cells, usually in small irregular groups or masses, separated by an abundant and fully-formed fibrous stroma resulting from the irritation and proliferation of the pre-existing connective tissue of the part (Fig. 87). In the older and more central parts of the tumour degenerative changes are often present. At the periphery the growth may be seen extending in all directions along the tissue-spaces and lymphatics, whilst a round-celled infiltration of the surrounding tissues is also common.

Where the stroma is very excessive, the cell-elements, and, indeed, the whole tumour, may undergo a considerable degree of atrophy, owing to compression of the nutrient vessels, as well as of the tumour-cells themselves, constituting the variety known as **atrophic scirrhus.**

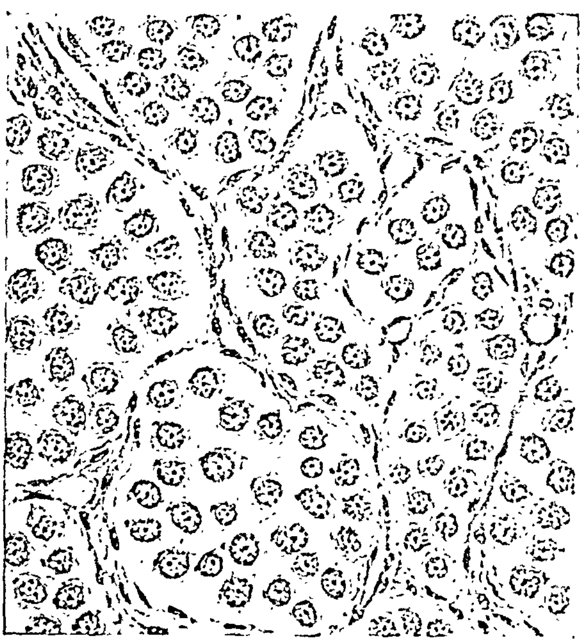


FIG. 88.—'ENCEPHALOID' OR MEDULLARY CANCER OF THE BREAST.

The actively proliferating epithelial cells show an alveolar arrangement with a surrounding fibrous-tissue stroma containing the blood-vessels. (× 300.)

(ii.) **Encephaloid, Medullary,** or **Soft Cancer** (Fig. 88) is a term applied to a growth of a similar nature, in which the stroma is much less abundant than the cell-elements. It constitutes a rapidly-growing tumour, much softer than the scirrhus form, and very early infiltrating surrounding parts and affecting neighbouring lymph-nodes. The skin over such a tumour, *e.g.* if in the breast, is stretched, and dilated blue veins may be seen through it. Ulceration is liable to occur, and from the surface a foul, projecting, hæmorrhagic, fungating mass develops. Encephaloid cancer may attack the breast, pancreas, liver, kidney, and other glandular organs.

On section it is found to be composed of a soft whitish or pinkish-white mass, somewhat resembling brain-substance (hence the term 'encephaloid'). It is usually very vascular, perhaps even pulsating, and hæmorrhagic extravasation into its tissues and necrotic changes are not uncommon. An abundant juice is obtained on scraping.

Colloid Cancer results from a degeneration of the epithelial cells of any of the above-described types of cancer. Its most frequent site is within the abdominal cavity in connection with cancers arising from the stomach or intestine, or occasionally from aberrant portions of

intestinal mucosa, etc. It may spread widely in the peritoneal cavity, and has then to be distinguished from a primary endothelioma of the serous membrane itself. To the naked eye it presents a fine, spongy texture, the spaces being filled with translucent gelatinous material varying in consistence. Microscopically, the epithelial cells are progressively replaced by a structureless ' colloid ' or ' mucoid ' substance. Towards the growing margin, the cells may be seen in process of degeneration, globules of the material forming within them and pressing the nucleus to one side.

Hypernephroma is a peculiar sort of tumour which forms about 70 per cent. of all renal growths. The exact nature of the tumour is uncertain, and it is regarded as being an atypical carcinoma arising in the renal tubules. Two main varieties occur, the slowly-growing encapsulated growth bearing a strong resemblance to adrenal structure, and the more rapid variety in which the cells show a papillary or tubular arrangement. The tumour may reach a considerable size and is then usually lobulated and may contain areas of hæmorrhage or cystic degeneration. The upper renal pole is the site of origin in 50 per cent. of the cases. Metastases occur fairly early, spreading by the veins, and show a tendency to form in the bones, particularly those of the skull, vertebræ, and limbs.

Endotheliomas.—The **endothelial cells** of blood-vessels, lymphatic vessels and spaces, and serous cavities, are, physiologically speaking, lining cells; but, as they are originally derived from the mesenchyme, they may show reversion to pulp-tissue characters. This tendency is seen in inflammation, both acute and chronic, in which these cells proliferate and take an active part in the reactions against organisms and their toxins, and in the reparative processes seen in granulation-tissue. Marked, and sometimes extreme, proliferation of the cells of the reticulo-endothelial system—for example, those of the adenoid reticulum of the lymph-nodes, as in some forms of tuberculosis, or in the pulp of the spleen, *e.g.* in Hodgkin's disease (lymphadenoma) or in Gaucher's disease—may lead to appearances closely simulating neoplastic transformation. Indeed, in the last-mentioned condition, Gaucher's disease, opinions still differ as to whether it is of chronic infective or of neoplastic nature, *i.e.* an ' endotheliosis ' or an ' endothelioma.'

Definite tumours of endotheliomatous nature are by no means rare, and form a considerable group, which as a class are distinctly less malignant than the sarcomas, or carcinomas, to which they often bear close structural resemblances. They are usually slow in development, but often recur locally after removal, and may in time affect lymph-nodes or form metastases in internal organs. Their most important sites are the meninges of the brain and cord, and the pleura or peritoneum, but they may occur in any part of the body. The cells constituting an endothelioma are derived from the pre-existing endothelium of the region, and they become spherical or spindle in shape, and take on independent growth. The tumour may start in the lymphatic clefts, which then appear to be filled with cuboidal cells, forming a cellular network having some general resemblance to a carcinoma. In some cases the cells affected are those lining the

smaller lymphatic vessels, and in others this may involve especially those occurring in the vascular sheaths, forming a cellular investment to the smaller vessels—**perithelioma** (Fig. 89). In a third group the endothelium which takes on morbid growth is that which lines the blood- or lymph-vessels themselves.

The endotheliomas which occur in the central nervous system are usually composed of spindle-shaped cells, and often tend to show a curious arrangement in whorls, something like those of a 'cell-nest.' The central portions of these little masses frequently undergo a variety of hyaline degeneration, and may subsequently become calcified, and, from the resemblance of these gritty particles to sand, such tumours are called **psammomas.** Such endotheliomas of the meninges or **meningiomas** are not uncommon, and arise most probably from arachnoidal cells. They are generally though not always superficial, and are then readily removable, and may not recur after operation. Multiple meningiomas may occur, especially in association with neurofibromatosis (von Recklinghausen's disease, see p. 204).

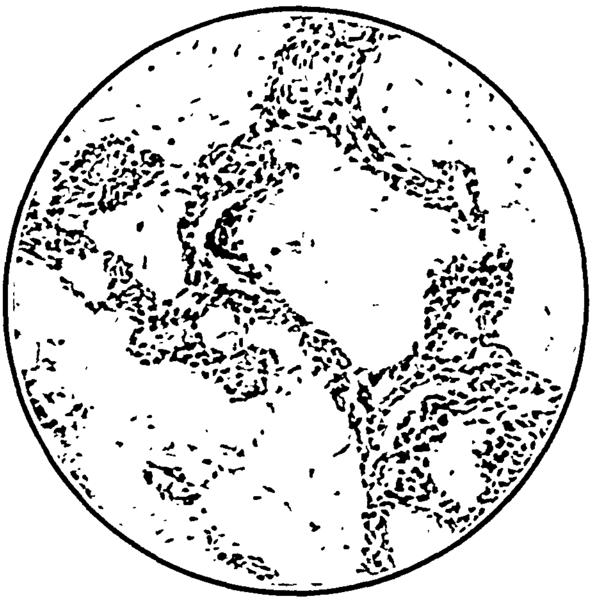


FIG. 89.—PERITHELIOMA. (× 120.)

Treatment of Cancer.—That cancer can be extirpated in a considerable percentage of cases by early and well-planned operation can now be taken for granted, but the success or otherwise of operative treatment depends largely upon the stage reached by the disease.

The ideal **operative** treatment is the removal of the tumour, together with a wide margin of healthy tissue around it, or, in some cases, of the whole organ or limb affected, as well as of the lymphatic area concerned, if practicable, in one mass, so as not to cut across the lymphatic vessels passing from the growth to the lymph-nodes. The wide area which may be permeated by the cancer-cells, and the impossibility of recognizing by the naked eye their presence in the tissues, explains the necessity for the extensive scope of such operations, and the only too frequent 'recurrence' locally or along the course of the lymph-channels when the excision has been too limited. The use of the **electro-cautery knife** and **needle** for the making of incisions and for excising malignant growths constitutes a notable advance in surgical technique, the cancer-cells encountered being killed instead of being disseminated by the ordinary surgical knife. The essential factor of

success is early and accurate diagnosis, followed by adequate operation, but it is only from **early diagnosis** that we can hope for the best results.

Recent advances in radiology have led to the increasing employment of X-ray and radium therapy as an adjuvant to surgical procedure. Their value and limitations and their methods of employment, both before and after operation, are discussed on pp. 303, 310.

Many workers are still investigating the **chemotherapy** of cancer. Colloidal metals, especially lead, radio-active bismuth, a double colloid of sulphur and selenium ('SSe'), radio-active selenium ('R.A.S.'), followed by deep X-ray treatment in cautiously graded doses, and other substances, have been tried, but, except in the hands of their originators, the results with these methods are so far not sufficiently encouraging for much reliance yet to be placed upon them.

Interesting experiments are also being carried out to investigate the possible influence upon new growth, retarding or accelerating as the case may be, of the hormones of the ductless glands, *e.g.* the sex-hormone prolan A excreted in the urine, but the value or otherwise of the results has still to be determined.

Many substances have been vaunted as 'cancer-cures,' but careful trial under trained observers has hitherto resulted in disappointment. In some few instances the growth of the tumour has been hindered by tying the nutrient vessels, *e.g.* the external carotid and its branches in malignant tumours of the head, and pain has been relieved by division of sensory nerves, nerve-roots, or even certain of the sensory tracts of the spinal cord itself. In ulcerating cases, the adoption of careful aseptic methods and the use of a suitable vaccine may reduce the inflammatory reaction, and cause temporary improvement. In the final stages, morphia can alone be depended upon to give to the patient some relief from pain.

B. Teratomas.

By the term **teratoma** is signified a mixed tumour which includes in its substance derivatives of all three germinal layers (epiblast, mesoblast, and hypoblast). The term **dermoid** is retained for tumours of the nature which contain only tissues derived from the epiblast. Sometimes the tissues are arranged in a more or less orderly fashion, and represent comparatively well-defined types of adult tissue. On the other hand, the tissues may be incompletely differentiated and wanting in orderly arrangement, in which event malignant change may sometimes supervene. The origin of these tumours is not definitely known. Hitherto the general impression has been that they may be due to the inclusion within the body of the products of another individual of the same species, such inclusion developing along its own lines and being autonomous. Recent research, however, appears to throw some doubt on this view, and it seems possible that the development of such abnormalities may be 'induced' in the body of the individual itself during embryonic or fœtal development.

The commonest example of this type of growth is the '**dermoid**' **of the ovary,** which may be unilocular and grow to a large size. Its lining-wall is largely ectodermic in nature, and from it an abundant development of cutaneous appendages, such as hair, nails, teeth, nipples, mammæ, etc., is sometimes observed. Most commonly the cyst is filled with greasy sebaceous material and with an abundance of hair, which is said to be influenced in the same way as that on the scalp, becoming grey or being shed at the same time. Sometimes the tumour is more complex, containing structures such as bone, muscle, gland-tissue, etc., which are formed from all three layers of the embryo; in some rare instances large portions of an embryo, such as imperfectly developed viscera or a limb, are recognizable. Similar dermoids or teratomas are found in the **testis** and along the track of its descent in the retro-peritoneal tissues, and they often become malignant, and in that case metastasize early. They may also occur in the thorax and sacral region. In some cases of teratomas the Aschheim-Zondek reaction, usually employed as a test for pregnancy, may be positive for the presence of prolan B.

Teratoid Tumours are a somewhat analogous group due to intermingling of tissues early in development, *e.g.* rhabdomyoma of the kidney. Tumours may also arise from developmental errors in connection with embryonic clefts, *e.g.* in the neck, or along the middle line of the body, or from fœtal remnants which should normally become atrophied and obliterated. These tumours are frequently cystic in character, and may conveniently be dealt with shortly in the following section on cysts.

CYSTS.

Cysts are more or less rounded cavities, usually possessing a distinct lining membrane, and with fluid or semi-fluid contents. For practical purposes they may be classified as follows:

I. **Cysts of embryonic or fœtal origin,** or arising in connection with embryonic or fœtal remains.
II. **Cysts arising from the distension of pre-existing spaces (distension cysts).**
III. **Cysts of extraneous origin.**
IV. **Cysts** (or, more accurately, **false cysts** or **pseudocysts**) **of degeneration.**

I. Cysts of Embryonic or Fœtal Origin, or arising in Connection with Embryonic or Fœtal Remains.

1. **Dermoids** are characterized by the existence in abnormal situations of cavities lined with squamous epithelium, from which may be developed such cutaneous appendages as hairs and sebaceous glands, whilst the cavity is usually occupied by sebaceous contents. The structure of the lining wall is very similar in nature to skin or mucous membrane, consisting of stratified epithelium, from which a considerable growth of sebaceous glands and hair-follicles often takes place.

If teeth or more complex tissues, such as bony alveoli, islands of cartilage, mammary glands, nipples, etc., develop in such a cavity, it should be looked on as a teratoma.

Several varieties of 'dermoids' are described:

(*a*) **True or Congenital Dermoids** ('Fissural' or 'Sequestration' Dermoids) are cysts arising from the incomplete disappearance of surface epithelium in situations where, during embryonic life, surface developmental segments coalesce. Thus, in almost any part of the middle line of the body such 'fissural' dermoids may develop, owing to the fact that there is here a union of two lateral segments. Similarly, they are not uncommon about the face and neck, occurring along the lines of the facial and branchial clefts. Perhaps the common-

FIG. 90.—DERMOID CYST AT THE ROOT OF THE NOSE.

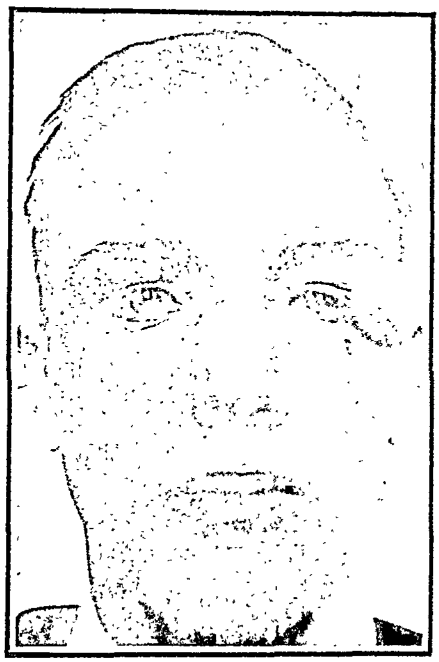


FIG. 91.—DERMOID CYST GROWING AT THE OUTER ANGLE OF THE ORBIT.

est position for them in this region is the upper portion of the orbito-nasal cleft (Fig. 90), behind, and to the outer side of the eye (Fig. 91). It is not unusual to find the subjacent bone of the skull defective, and a pedicle extending from the deeper aspect of the cyst, connecting it with the dura mater. Such dermoids appear as rounded, definitely limited tumours, firm and elastic to the touch, and over which the skin glides freely, but they are usually somewhat adherent to the deeper parts. This form of dermoid may be removed without difficulty, but in those occurring about the scalp, with the bone hollowed out beneath them, it is perhaps advisable to delay operation till adult life, unless they are rapidly increasing in size. The reason for this is that the bone gradually closes in around the pedicle, and thus cuts off the

communication with the cranial cavity. In some cases it may be difficult to remove the whole of the lining membrane by dissection, and under these circumstances the portion left behind should be destroyed by cautery or caustics; otherwise, recurrence is almost certain to follow.

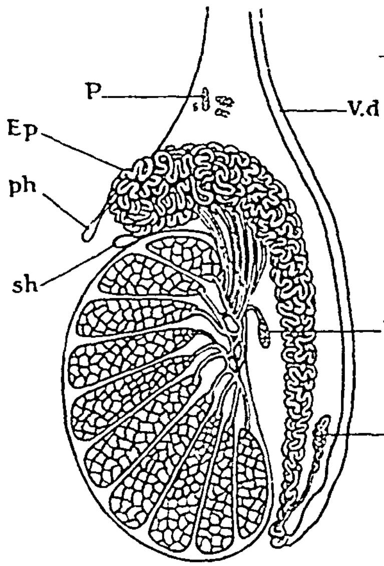


FIG. 92.—DIAGRAM OF ADULT TESTIS, TO SHOW RELATION OF VESTIGIAL REMAINS.

P, Paradidymis (organ of Giraldés); Ep, epididymis; ph, pediculated hydatid; sh, sessile hydatid; v.H, vas aberrans of Haller; V.T, vas aberrans of rete testis; V.d, vas deferens.

(*b*) **Tubulo-dermoids** arising in connection with embryonic or fœtal canals and passages such as the thyroglossal and cranio-pharyngeal ducts, and the post-anal gut, and with the sacro-coccygeal region, as well as various other congenital abnormalities such as spina bifida, etc., and also those connected with the pituitary and pineal regions, are described elsewhere.

(*c*) **Ovarian and Testicular Dermoids** have been referred to already.

2. **Cysts** occasionally arise in connection with the formation of the **Teeth**; such have already been described in connection with the odontomes, the follicular (dentigerous) and multilocular (adamantinomas) cysts being the ones most commonly seen.

3. Various **cysts** may develop in connection with the **remains of the Wolffian body,** as also from its **tubules** and **duct.** This body (the mesonephros) arises on the posterior abdominal wall, together with the kidney and testis, and part of it enters into the formation of the latter: hence the fact that its remains are closely associated with that organ in the scrotum (Fig. 92). In the **male** the Wolffian body atrophies almost completely, being represented by a few blind tubules, situated close to the epididymis, and known as the paradidymis, or organ of Giraldés (P). The majority of the ducts of the Wolffian body form the vasa efferentia testis; a few,

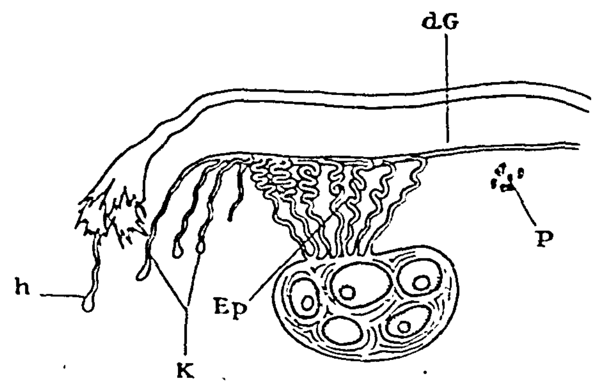


FIG. 93.—DIAGRAM OF OVARY AND FALLOPIAN TUBE, TO SHOW POSITION OF FŒTAL REMAINS.

h, Hydatid of Fallopian tube; K, Kobelt's tubules with hydatids; Ep, epoöphoron (organ of Rosenmüller); P, paroöphoron; d.G, duct of Gaertner.

however, are attached only at one end, and their free ends (ph, V.T) may become dilated, and form small cysts, situated close to the hydatid of Morgagni (sh), which structure represents the remains of the **Müllerian body** and **duct.** It is possible that an encysted hydrocele of the epididymis sometimes arises from one of these unobliterated tubules. The main duct of the Wolffian body forms the lower portions of the epididymis (Ep) and vas deferens (V.d).

In the **female** (Fig. 93) the remains of the **Wolffian body** may sometimes persist as a series of closed tubes (paroöphoron, P) in the broad ligament not far from the ovary. **Cysts of the Paroöphoron** may arise in connection with this structure, and are characterized by their inner walls being liable to become the seat of proliferating papillomas. The Wolffian tubules can almost always be recognized in the broad ligament, constituting the epoöphoron (Ep), parovarium, or organ of Rosenmüller. **Parovarian Cysts** formed from the distension of this structure are usually unilocular, and filled with a clear limpid serous fluid; they have no definite pedicle, growing within and separating up the layers of the broad ligament. Some of the terminal tubes may be converted into small cysts which project from the fimbriated end of the Fallopian tube, and are known as the cysts of **Kobelt's tubules.** The main Wolffian duct generally atrophies, but occasionally persists between the layers of the broad ligament close to the uterus, and may open in the vagina near the urethral orifice, being then known as **Gaertner's duct** (d.G). Cysts may occasionally arise in connection with this structure, projecting into the lateral fornix of the vagina.

4. The **processus vaginalis,** or **funicular process,** is the term applied to the protrusion of peritoneum which precedes the testis to form the tunica vaginalis, and which in the female accompanies the round ligament as the **canal of Nuck.** Normally it becomes obliterated, but sometimes portions remain patent, and become distended with a clear straw-coloured serous fluid, constituting in the male an **encysted hydrocele of the cord,** and in the female a **hydrocele of the round ligament.**

5. Cysts arise occasionally in connection with some irregular development of the lymphatic spaces; thus, in the neck the so-called **cystic hygroma** is in reality a congenital **cavernous lymphangiectasis,** to be distinguished from **hydrocele of the neck,** a simple dilatation in a branchial cleft, lined by epithelium surrounded by fibrous and lymphoid tissue.

II. Cysts due to the Distension of Pre-existing Spaces.

1. **Exudation- or Distension-Cysts** arise from the dilatation of various closed spaces or cavities such as glandular acini, bursæ, etc. Such spaces may thus be lined with epithelium or endothelium. As illustrations of **epithelial cysts** may be mentioned those which arise in connection with the thyroid gland, and also conditions due to the distension of the central canal of the spinal cord (syringo-myelocele), and those forms of ovarian cysts which arise from distension of Graafian follicles.

In some tumours, analogous cysts may be formed by the distension of neoplastic gland-spaces, *e.g.* especially in the cerebral and other metastases following primary bronchial carcinoma.

Exudation-cysts, the walls of which are lined by **endothelial** cells, are

of more frequent occurrence. Enlargements of bursæ, hydroceles of the tunica vaginalis testis or of the funicular peritoneal process, and some forms of 'ganglia' in connection with the sheaths of tendons, are of this nature.

Serous cysts may arise from the distension of lymph spaces, producing uni- or multi-locular cavities, lined with endothelium, and containing a limpid straw-coloured fluid. They are seen most commonly in the neck, axilla, or breast, and in the latter may be surrounded by dense fibrous tissue. They may be regarded as **cavernous lymphangiectases** (see above). Another variety may arise from diverticula of serous sacs such as the pericardium.

Adventitious bursæ arise as a result of repeated irritation, and are dealt with in Chapter XVIII.

2. When a collection of blood forms in a pre-existing cavity, a so-called **Cyst of Extravasation** is produced. This is found in the cavity of the peritoneum, especially in the pelvis or in the tunica vaginalis (hæmatocele), and also occasionally on the surface of the brain, constituting one form of arachnoid cyst.

3. **Retention-Cysts** arise from obstruction to the escape of some natural secretion from a gland-duct or tubule. The cavity thus formed is lined with epithelium, whilst, owing to the irritation produced by the tension, a fibro-cicatricial wall of varying thickness is developed outside. The commonest variety is the *sebaceous cyst*, which occurs on the scalp and which is full of sebaceous material. The *mucous cysts* occurring in the buccal mucous membrane are of a similar nature and are also not uncommon. There is sometimes a considerable formation of intracystic growths, especially in the breast, whilst the contents generally consist of the inspissated secretion, perhaps mixed with blood. Retention-cysts may develop in connection with any glandular tissue. The majority are described under the appropriate headings, *viz.* mammary cysts, renal cysts, pancreatic cysts, etc.

III. Cysts of Extraneous Origin.

These may occur apart from any embryonic condition or pre-existing cavity. The following varieties may be described:

1. An **Implantation-Cyst** is one which arises from the accidental intrusion into the subcutaneous or submucous tissues of epithelial cells which retain their vitality, and are enabled to develop a cyst very similar in nature to a dermoid; in fact, it may be looked upon as an acquired or traumatic dermoid. Such an occurrence is brought about usually as the result of an injury, especially from punctured wounds; thus, cysts of this nature may be produced in the fingers or palm of the hand, or in the sole of the foot, or elsewhere as a consequence of the penetration of some sharp instrument, whilst they are also occasionally seen in the cornea or the anterior chamber of the eye, following accidental injury or an iridectomy. Such cysts remain 'simple' in character, and clinical signs and treatment are similar to those of a dermoid cyst (see p. 227).

2. **Parasitic Cysts** are produced by the growth within the tissues of certain animal parasites, especially worms, in certain stages of their

development. Thus, in the disease known as **Trichinosis** (trichiniasis or trichinelliasis), derived from eating infected pork, the larval stage of *Trichinella* or *Trichina spiralis*, a minute round-worm develops in large numbers in the muscles, and becomes surrounded by a capsule which usually subsequently undergoes calcification.

The most important of these parasitic cysts is that caused by the development within the body of the scolex stage of *Tænia echinococcus*, giving rise to what are known as **Hydatid Cysts**. This disease is more prevalent in Australia and New Zealand than in this country. *Tænia echinococcus* (Fig. 94) is a small tape-worm, less than half an inch in length, which in very large numbers may inhabit the intestinal canal, especially of dogs, in which it is very common. It consists of four segments, the posterior one being larger than the rest of the worm, and containing the mature genital organs. When mature, this last segment becomes filled with ova, some 500 or so in number, which are discharged, and these find their way into the human stomach from handling the dog, or, though probably less commonly, by the medium of water or uncooked vegetables, such as water-cress, which have been contaminated with the dog's excreta. The process of digestion sets the embryo free, and by means of a crown of little hooks which it possesses, as well as four suckers, it is enabled to bore its way through the walls of the stomach, and thence travels by the portal vein to the liver, where it may settle down, or, less frequently, be carried on to the lung, or some other part of the body, where it becomes encysted. A sac forms, which originally consists of three layers: externally, a fibro-cicatricial layer, the result of the irritation caused by its presence; then an intermediate laminated layer of chitinous material (true cyst-wall, ectocyst or 'hydatid membrane'); and finally a lining of a protoplasmic germinal layer (endocyst), from which may be developed solitary tænia heads or scolices, also provided with four suckers and a circlet of hooks; sometimes groups of scolices, known as brood-capsules, may arise in the same way (Fig. 95). Daughter-cysts are not infrequently formed from the scolices, and they in their turn may pass through the same changes, although as a rule they are barren. Occasionally even the main cyst may be sterile (acephalocyst), and in such cases the walls become very definitely laminated. The fluid contained in the cyst varies much in amount, with a specific gravity of about 1007; it is colourless, but slightly opalescent, limpid, containing a trace of albumen, and a considerable amount of sodium

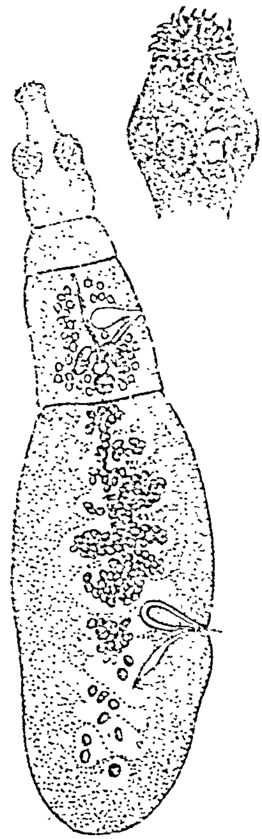


FIG. 94.—TÆNIA ECHINOCOCCUS. (× ABOUT 20.) The upper figure is an enlarged drawing of the head, showing the circle of hooklets and suckers.

chloride. On examining the fluid microscopically, the characteristic hooklets, if present, can be seen. The organs usually affected by hydatid disease are especially the liver in some 70 per cent. of the cases, the lungs in about 10 per cent., the remaining 20 per cent. being found elsewhere, *e.g.* in the kidneys and brain, but any part of the body may be attacked. Occasionally in the liver, and usually in bone, multiple cysts develop quite distinct from each other, and with no general cyst-wall (exogenous multiplication). This can occur only when the ectocyst is thin, allowing the scolices, which have a retractile neck, to push through and 'swarm off' into surrounding tissues.

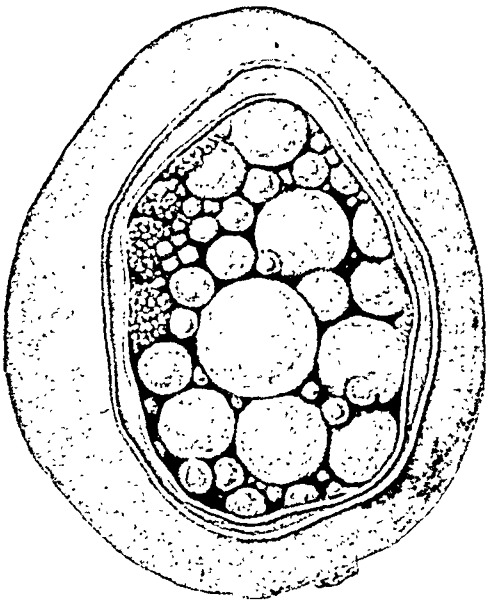


FIG. 95.—HYDATID CYST (DIAGRAMMATIC), SHOWING DAUGHTER-CYSTS AND BROOD-CAPSULES GROWING FROM THE WALLS. (AFTER BLAND-SUTTON.)

Uncomplicated hydatid cysts may give rise to no special symptoms, except those caused by their size and situation, and they are likely to go on growing until operative treatment becomes imperative on account of some complication, or from the size of the mass. At any time the cysts may rupture, either spontaneously or as the result of some injury; if into a serous cavity, such as the peritoneum or pleura, this becomes infected, and an abundant development of scolices and cysts ensues, giving rise to considerable localized inflammatory reaction; moreover, the escape of the cyst-fluid may cause urticaria and perhaps serious toxæmia, owing to the presence of some toxic substance.

Occasionally the parasites die out spontaneously, and then the cyst shrivels up, and the laminated walls and daughter-cysts form a firm leathery mass, the contents of which may perhaps later become infiltrated with lime-salts and of the consistency of wet mortar; a thick fibro-cicatricial capsule encloses the whole. In other instances suppuration takes place within the cyst, and an abscess results. If acute, it bursts, either externally or into some serous cavity or hollow viscus. Sometimes the abscess becomes chronic and encapsuled, and may then remain quiescent for years.

Assistance in the diagnosis of hydatid disease may be obtained by the use of certain laboratory tests:

(1) The **precipitin test,** depending upon the development of a reaction between the patient's serum and hydatid fluid. It is accurate in about 65 per cent. of cases, but is of value only with controls.

(2) The **complement-fixation test,** which is specific, depending upon the presence of hydatid antigens in the patient's serum. It is only positive, however, in about half the cases.

(3) The **intradermal test** (Casoni's test) may be performed by

inoculating between the layers of the skin hydatid cyst-fluid obtained from a known case of the disease, either human or animal. A positive reaction consists in the appearance within a few minutes of a urticarial weal—a raised whitish, button-like area of œdema at the site of inoculation, surrounded by a zone of erythema, a delayed reaction in some cases following later, usually in about twenty-four hours, gradually subsiding in two or three days. Generally speaking, in this test a negative finding is more valuable as pointing to the probable absence of hydatid disease, than is a positive reaction as an indication of its presence.

These tests should be repeated at least once if negative.

(4) **Eosinophilia** of a moderate degree is present in the earlier stages of the disease or where there has been leakage or absorption of some of the cyst contents.

For the diagnosis and treatment of hydatid cyst of the **liver**, see Chapter XXXVII. In other regions, if the mass cannot be removed by dissection, reliance must be placed on drainage, *e.g.* by the method known as 'marsupialization' (*i.e.* the formation of a pouch, the opening being isolated to prevent the infection of the surrounding raw tissues), where its situation renders this practicable, or aspiration, perhaps followed by the replacement of the contents by 1 per cent. formalin, left in for at least five minutes and then withdrawn.

IV. Pseudocysts or False Cysts.

1. **Pseudocysts** may form **around foreign bodies,** which thus become encapsuled. They are lined with granulation tissue or with endothelium, surrounded by fibro-cicatricial tissue.

2. **Blood-Cysts** are of various origins. Some arise from extravasation of blood, and are then filled with coagulated blood, or a thin serous fluid with a varying amount of laminated fibrin. In some cases a so-called blood-cyst is really a soft sarcoma into which hæmorrhage has occurred; but a few instances are on record in which a thin-walled cavity existed, occupied by blood, and readily refilling after it had been tapped, and with no evidence of any growth. Such conditions have been most frequently observed in the neck.

3. **Pseudocysts due to Degeneration** arise in connection with tumours, especially those in which the blood-supply is not very abundant. Thus, mucoid degeneration is not uncommon in fibromas, fibromyomas, chondromas, and in some forms of cancer. Occasionally such pseudocysts are formed in the sarcomas from this cause, but more frequently as a result of hæmorrhage. Degenerative pseudocysts are of frequent occurrence in some of the more slow-growing varieties of glioma, notably in astrocytomas. Closely analogous to this form are certain cystic tumours of the central nervous system, especially the cerebellum, a nodule of angiomatous or sometimes gliomatous tumour, or a mixture of these, being found in the cyst-wall. The removal or destruction of this mural nodule is essential to the surgical cure of such cysts. In **Lindau's disease** or **syndrome** a cerebellar cyst of this nature may be associated with tumours in other organs, such as cavernous angiomas of the eye or liver, and sometimes congenital cystic disease of the kidney.

CHAPTER VIII.

WOUNDS.

A WOUND has been defined as the forcible solution of continuity of any of the tissues of the body; but the term is more commonly limited to injuries of the soft parts, involving the skin or mucous membranes. Lesions in which the skin does not participate are spoken of as contusions.

A **Contusion** results from external violence causing hæmorrhage into and laceration of the subcutaneous tissues, and may possibly be associated with injuries to deeper structures. The signs are usually very obvious, *viz.* **pain, bruising,** or discoloration of the part, and **swelling.** The amount of bruising varies with the part injured and the severity of the lesion; thus, in the eyelids, scrotum, and vulva, where the tissues are lax, the ecchymosis will be very extensive and of a black colour; on the scalp there is but little swelling unless bleeding occurs beneath the aponeurosis of the occipito-frontalis. Again, the condition of the patient's general health influences the amount of blood effused; a strong man in good training does not bruise nearly as much as those of a languid temperament and relaxed tissues. Blebs and bullæ may form over the injured spot, especially in connection with fractures. The changes that occur in a bruise are well known, the colour passing from a blackish-purple through various shades of brown and green to a yellow, which gradually fades and disappears; this is due to the disintegration of the red corpuscles, and staining of the tissues by the hæmoglobin thus set free, or by the products formed during its removal. When hæmorrhage occurs deeply, it is often some days before the bruise 'comes out,' and this may occur at some distant spot, *e.g.* in the eyelids after a blow on the scalp, whilst it may travel along the muscular and fascial planes under the influence of gravity.

In a bruise or ecchymosis, the tissues are, as a rule, merely infiltrated with blood; but occasionally they are torn asunder, and then the extravasation is more localized, and may constitute a fluid swelling or **Hæmatoma.** It somewhat resembles an abscess to the touch, but differs from it in having supervened immediately after an injury, and in having appeared without any heat or other sign of inflammation; moreover, though at first fluid and soft, it soon becomes harder, whereas an abscess is preceded by a stage of brawny infiltration, and the softening occurs later. The subsequent history of a hæmatoma varies somewhat according to circumstances. (*a*) Fibrin may be deposited peripherally, leaving for a time a fluid centre, which gradually disappears, and the whole is finally absorbed. This is well exemplified in a subpericranial cephalhæmatoma, where the contrast

between the peripheral fibrinous deposit and the fluid centre, through which the skull can be felt, is sometimes so accentuated as to give the sensation of a depressed fracture. (*b*) The fluid portion of the blood may be absorbed almost entirely, and the solid fibrinous residuum may become organized into a firm fibroid tumour which persists indefinitely; the mass is more or less laminated, and not unfrequently pigmented; and in some cases calcification occurs. (*c*) The fibrin may be entirely absorbed, and a slightly pigmented fibrous capsule formed containing serous fluid, and constituting a definite cyst; this is best seen in connection with the cerebral tunics (*arachnoid cyst*). (*d*) Suppuration may ensue owing to auto-infection from within the body, or from an invasion of organisms through abraded skin.

The **Treatment** of a bruise usually consists in keeping the part at rest, and applying cold or evaporating lotions. The effusion of blood may be hindered, if the case is seen early, by firm bandaging of the part over a compress of cotton-wool. In the later stages absorption of the blood may be hastened by massage. In the severer cases, where blebs or bullæ have formed or there is a likelihood of the skin sloughing, it must be carefully washed and rendered aseptic, and, if need be, wrapped in an aseptic dressing. When a tense and painful hæmatoma exists, as under the fascia lata of the thigh, recovery can be hastened and pain relieved by an aseptic puncture, followed by careful compression. In general bruising of the body from a fall or extensive injury, pain can often be relieved by applying fomentations or by a hot bath. There is usually a certain amount of fever and constitutional disturbance for a few days, and these are dealt with by purgatives and a suitable limitation of diet. In case of suppuration the hæmatoma should be incised and drained.

Open Wounds.—An open wound may be defined as a solution of continuity of any superficial part of the body, including skin or mucous membrane. Various kinds of wounds are described, such as the incised, lacerated, contused, punctured, poisoned, and gunshot; but, of course, the most important distinction to draw is between the infected and the non-infected.

I. **Incised Wounds.**—An incised wound is one made by any sharp cutting instrument, but occasionally one not produced in this manner may be characterized by similar appearances, *e.g.* the skin of the knee or elbow may be cleanly split open from falling on it with the limb flexed, and occasionally a policeman's truncheon will lay open the scalp almost as evenly as if a knife had been employed.

The special features of an incised wound are as follows:

1. The hæmorrhage is free, from the fact that the vessels are cleanly divided. The amount necessarily depends on the size of the vessels involved, and the vascularity of the part; its continuance, upon the density of the structures allowing or not of contraction and retraction of the severed ends.

2. Retraction of the lips of the wound also occurs, the amount depending upon the elasticity and character of the part involved and the degree of tension to which it is exposed.

3. Bruising of the margins of the incision is absent, so that under ordinary circumstances rapid healing (by first intention) should obtain. The surfaces, to begin with, are lined by a microscopic layer of damaged tissue, some of which may be actually dead; but if suitable precautions are taken, this is absorbed, and in no way interferes with satisfactory union.

The chief dangers of an incised wound are: (1) Hæmorrhage; (2) injury to subcutaneous structures, such as nerves, tendons, muscles, etc.; and (3) the risks involved from infection.

Treatment of Incised Wounds.—Seven essentials must be attended to if healing by first intention is to be obtained, *viz.*:

(i.) **The Arrest of all Bleeding.**—General oozing may be stayed by exposure to the air or the pressure of an aseptic swab. Divided arteries and veins will need a ligature, but if situated close to the skin, they may sometimes be secured by passing under the bleeding spot the needle used for the suture.

(ii.) **Sterilization of the Wound and its Surroundings.**—In casualty work asepsis cannot be always assured, as the wound, though cleanly cut, is made through dirty skin, and portions of clothing, dirt, and splinters of wood or glass may be carried in. Under these circumstances the wound and its surroundings must be thoroughly purified.

(iii.) **The coaptation of the opposed surfaces** by means of **sutures** may now be undertaken. The substances employed for this purpose are fine silver wire, silk, horsehair, silkworm gut, and catgut. In casualty work, and for parts of the body where but little scar is subsequently desirable, as in the face, horsehair and silkworm gut, being non-absorbent, are the best; but in ordinary operative work, which will be more certainly aseptic, fine catgut or silk may be used. There are three chief varieties of sutures, *viz.* the buried, the deep, and the superficial.

Buried sutures may be safely inserted in order to hold the deeper parts of a wound together, if both they and the wound are aseptic, and there they may remain indefinitely; if, however, they are unabsorbent, *e.g.* silk or silkworm gut, irritation or tension may lead to suppuration with a view to the elimination of the stitch even after lengthy intervals. Catgut of varying thickness is therefore the best material to employ, chromicized to a suitable degree according to the length of time it is desired to maintain its action. Where permanent retention of the suture with a view to strengthening the part is desirable, and yet an element of tension is present, as in some wounds of the abdominal wall, it may be wise to employ living sutures formed of strips of fascia lata taken from the patient; these, it has been proved, are not absorbed, but remain incorporated in the part, thereby adding to its strength.

Deep stitches, or *sutures of relaxation*, are required in cases where there is difficulty in bringing the edges of the wound together, in order to transfer the tension from the healing margin to tissues further away, the edges being thereby relaxed.

Superficial stitches, or *sutures of coaptation*, must be so inserted as to bring the edges of the wound into contact without undue pressure,

and without any infolding of the skin. Various methods are employed, *viz.*: 1. The *interrupted suture* (Fig. 96, A), in which each stitch is separately finished off, the knot lying well to one side of the incision. This is generally utilized for wounds which are of irregular shape or in which there is tension. 2. The continuous *glover's stitch* (Fig. 96, B) is a useful form of suture. 3. The *blanket* or *buttonhole stitch* (Fig. 96, C) is the form of continuous suture which should be employed for extensive wounds or incisions, but should not be pulled tight. In it the needle, after traversing the lips of the wound, is carried under the slack of the thread, so that the loop of each stitch, as it is tightened, is maintained at right angles to the wound, whilst the intermediate

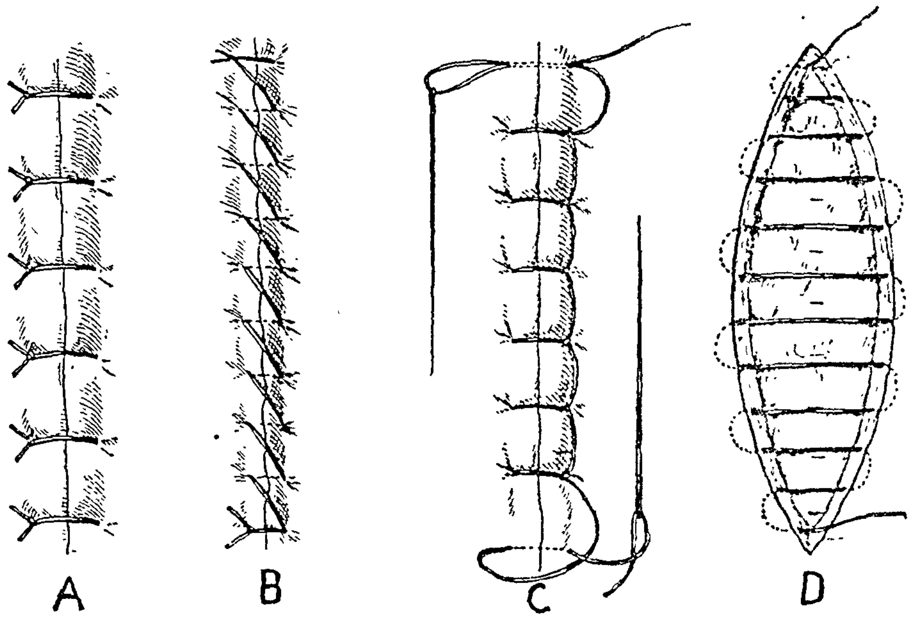


FIG. 96.—VARIOUS FORMS OF SUTURE.

A, Interrupted suture; B, continuous suture; C, blanket stitch. At the lower end the needle has just been passed, and the way in which it catches up the loop is indicated. At the upper end the method of finishing off is shown, *viz.* the needle is passed in the opposite direction to all the other stitches, the free end being left long, so as to enable it to be tied into a knot with the double thread which the needle has carried through. D, Halstead's intradermic or subcuticular stitch.

portion lies parallel to it. 4. Halstead's *intradermic* or *subcuticular stitch* (Fig. 96, D) is employed when very exact coaptation is desirable, and to minimize visible scarring, as in the face or neck. The deeper parts are first built up by buried sutures, and then a silkworm-gut stitch is inserted by a short straight needle through the skin, as in the diagram, passing parallel to the surface and alternately on the two sides. The suture is finally pulled tight at each end and left long. To remove it, one end is cut short, and then a steady pull on the other end draws out the remainder quickly and without pain. 5. A similar exact coaptation can be secured by interrupted sutures passed in the ordinary way about 1 centimetre from each edge, and then one of them is passed through the exact skin edge on both sides and tied to

the other end. This has been termed the eversion stitch, and may be used with advantage in fat subjects (Fig. 97); it prevents any part of the skin edges from being inverted. 6. Metallic clips, *e.g.* Michel's, are used by some surgeons instead of sutures; they are quickly and easily applied but have no real advantage.

Adhesive plaster is sometimes employed, but the wounds must be very small and insignificant which only require such treatment. A fine aseptic suture is in most cases preferable. Plaster is, however, extremely useful in the later stages to hold the wound together and prevent stretching of the scar tissue by muscular traction. Particularly is this valuable after abdominal operations where drainage has been employed.

(iv.) **Drainage** must, if necessary, be provided, in order to guard against the irritation and tension caused by retained blood or exudations. In casualty wounds, where there is doubt as to the completeness of the asepsis or hæmostasis, or where there has been much tearing

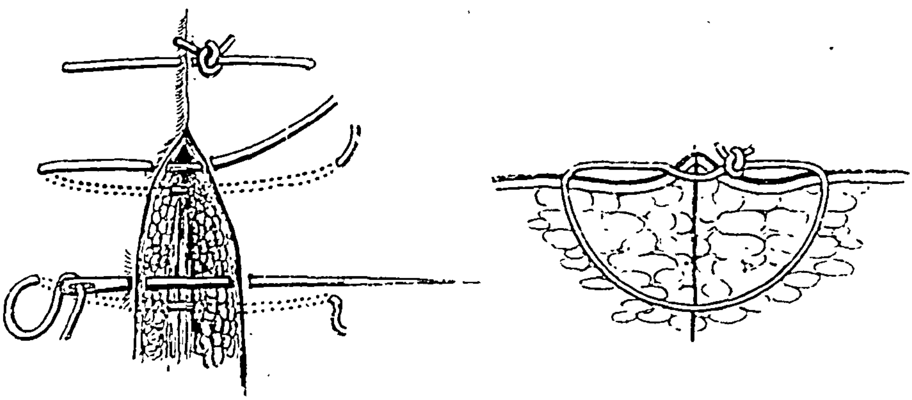


Fig. 97.—Eversion Stitch.

or laceration of tissues, it is often wise to insert a tube for twenty-four or forty-eight hours.

When drainage is required an indiarubber tube answers well; the end should be cut flush with the surface; a sterilized safety-pin may be passed through it so as to prevent it from slipping into the wound. For small wounds, a strand of horsehair or a strip of sterilized rubber glove or protective will usually suffice.

(v.) **All fresh sources of irritation and infection** of the wound must be excluded by some form of antiseptic or aseptic dressing.

(vi.) **Rest** to the injured part must be secured by such an arrangement of splints, slings, or bandages as may be necessary.

(vii.) The **general health** of the patient is a most important item. In an operation case the bowels should, if possible, be previously opened, and the patient's diet carefully regulated; in casualty work a good purge should be administered as soon as convenient.

An aseptic incised wound heals in from five to seven days, but the time to remove the stitches varies with the age and vigour of the individual, the part of the body, and the degree of tension required to close the wound. In aseptic operation wounds the stitches are

usually removed on the eighth day; but in the face it is often advisable to take them out earlier.

Many conditions may arise to *prevent* the healing of an incised wound by first intention, and they may be epitomized as essentially the reverse of the seven conditions mentioned above, *viz.*: (i.) Non-arrest of the bleeding, causing separation of the lips or deeper portions of the wound; (ii.) the presence of infected foreign bodies or failure of the antiseptic precautions; (iii.) non-apposition of the edges; (iv.) imperfect drainage, leading to tension on the stitches; (v.) late infection of the wound; (vi.) lack of rest to the part; and (vii.) constitutional conditions, such as deficient general vitality from disease or other causes.

II. **Lacerated or Contused Wounds.**—These injuries are caused by blunt instruments, by machinery, missiles, the wheels of a vehicle, etc. They are characterized by the following signs:

1. The hæmorrhage is as a rule but slight, since the vessels are torn across irregularly, and not cut cleanly; the middle and inner coats, which give way first, are curled up within the contorted outer coat, forming a barrier sufficient to prevent loss of blood. The vessels, being elastic, may be pulled out of their sheaths, and are sometimes seen pulsating upon the surface.

2. The amount of damage inflicted varies with the character of the injury, but is often so severe as to involve the death, at once or subsequently, of considerable portions of tissue. The skin is irregularly torn, and may be extensively stripped from underlying parts; muscles and tendons may be laid bare, or torn from their attachments; nerves may be lacerated; bones crushed and comminuted; joints laid open; and all these damaged tissues may be hopelessly infected by the dust of the roadway or the dirt and grease of machinery. When a limb is torn completely off, the tendons are often left long, and the muscular bellies project from their fascial sheaths as flabby congested masses, since the skin gives way at a higher point than the subjacent structures.

The **Progress** of the case depends largely upon the question whether or not the wound can be rendered aseptic.

In an **Aseptic** lacerated wound it may be possible to bring the edges together, and, even though they are a little bruised, healing by a slightly delayed first intention is possible. When the wound remains open, the dead tissue is absorbed or separated, and an aseptic granulating surface results. There may be some simple traumatic fever for a day or two.

If the wound is **Infected,** however, inflammatory phenomena supervene, as a result of which bruised and dead tissues have to be absorbed or cast off by a process of suppuration, which finally leaves a granulating surface. Three stages may be described in the course of such a case, *viz.*:

(*a*) The stage of injury, resulting in shock, which may be very severe if it includes extensive muscular injury or the crushing of large nerve trunks.

(*b*) The stage of inflammation and sloughing, which lasts a week, ten days, or more, according to circumstances, and during this

period various forms of infective trouble may develop, including secondary hæmorrhage, toxæmia, pyæmia, tetanus, and traumatic gangrene.

(*c*) The stage of repair by granulation, or prolonged suppuration, with exhaustion and hectic fever in the worst cases.

The results of the healing of injuries such as these may be quite satisfactory, or considerable trouble may be experienced at a later date from the implication of nerves in the cicatrix, or their paralysis; from the adhesions or cicatricial contraction of muscles and tendons, impairing the free mobility of the part; or from the deformity caused by the contraction of the scar.

The **Treatment** of contused and lacerated wounds varies with their character, and no absolute rule of practice can be laid down to suit all cases.

(*a*) **Immediate Treatment.**—All wounds of this nature are to be looked on as infected, and must be treated by excision of the dead or damaged tissues, efficient purification, and *immediate suture only if the surgeon is satisfied that complete asepsis has been secured.* Failing this, the wound is left open and packed with some suitable material, *e.g.* gauze soaked in a solution of flavine (1 in 1,000), and if infection is avoided delayed primary suture is undertaken.

(*b*) **Subsequent Treatment** depends on whether or not the measures adopted to obtain asepsis have been successful. If the wound remains free from infection, nothing special is required. If infection occurs, cellulitis and sloughing follow, and necessitate opening the wound freely, and following up any burrowing suppuration by free incisions. Fomentations, baths, etc., as for cellulitis (p. 60), will be required as long as the inflammatory process lasts, or the wound must be packed with gauze soaked in hypertonic saline solution. When the suppuration has ceased and the sloughs have separated, healing by granulation follows. It must be remembered that secondary hæmorrhage may occur when the dead tissues are detached. During this period inflammatory fever continues, and the patient's general health must be closely watched.

The question of **Amputation** will necessarily arise in dealing with the graver forms of lacerated wounds, although many limbs are now saved which would inevitably in former days have been sacrificed. Hard-and-fast rules cannot be laid down as to when to amputate and when not to do so; each case must be treated on its own merits. The following **general** points must first be carefully considered: (*a*) The *age* and *vitality* of the patient. An old person has less recuperative power than a young one, and hence a damaged limb may often be left in a youth which one would certainly remove in an elderly person. The vitality of the individual is perhaps even more important than the age, for some men at sixty are in a much more healthy and resistant state than others at forty. The habits, as to temperance, etc., must also be taken into consideration, and the existence of general diseases, such as diabetes or albuminuria, might induce one to resort to radical rather than conservative measures. (*b*) The vitality of the *extremity* injured. A leg has to be sacrificed more frequently than an arm,

since the vitality and reparative power of the latter are so much greater. (*c*) The presence or not of *infection* is of the greatest significance, since, if infection can be prevented, the chances of preserving the limb are greatly improved.

The **local** conditions which suggest or determine the performance of an amputation may be conveniently divided into two groups, *viz.* where amputation is essential, or where it is doubtful.

A. **Amputation** is certainly **called for**—

1. To trim up the stump of a limb torn off by machinery, or cut off by a railway train, or blown off in an explosion.

2. When the whole limb or one complete segment of it has been totally disorganized, or crushed to pulp, though still retaining its connection with the body.

3. In cases where gangrene is imminent or has supervened, especially if it is of the spreading type.

4. When severe infective symptoms develop in a case where an attempt is being made to save a limb, the retention of which was from the first doubtful, or when exhaustion supervenes from prolonged suppuration.

5. In severe compound lacerations of the foot *in old people*, involving the bones and laying open the common synovial cavity. Infection is likely to result in disease of the bones and joints, whilst the distance of the foot from the centre of the circulation increases the likelihood of gangrene.

B. **Amputation** is **doubtful** in the following conditions:

1. Compound comminuted fractures in parts other than the foot do not *per se* require amputation unless very extensive. By careful attention to antisepsis, free drainage, and the removal of detached fragments of bone and foreign bodies, which should usually be accomplished under an anæsthetic, limbs which would have formerly been condemned to amputation can not only be preserved, but also restored to a considerable degree of functional usefulness. The final decision will largely depend on the age, condition, and previous habits of the individual.

2. When the soft parts have borne the brunt of the injury, and have been extensively stripped from the bones, *e.g.* when the muscles of the forearm have been torn up in a machine accident, amputation is by no means an essential, provided that they can be restored to their original position, that there is a reasonable probability of their vitality being maintained, and that the utility of the limb will not be hopelessly impaired, as a result of lesions to the nerves, after the wound has healed. The surgeon has here to balance carefully the risk run if an attempt is made to save the limb with the value that the limb if saved will be to the patient.

3. Laceration of the main artery of a limb need not in itself determine amputation; but if in addition to this the bones, veins, or nerves are hopelessly injured, and especially in the lower extremities of old people, amputation should be undertaken without delay.

Reference must here be made to Trueta's experience in the Spanish Civil War: Trueta found that by applying the method of Winnett

Orr to extensive wounds of the soft tissues, whether associated with compound fracture or not, healing was expedited, septicæmia lessened, and mortality greatly diminished. The principles of treatment are excision of all dead and hopelessly damaged tissue and excision of wound edges, reduction of fracture if present, and the wound is plugged with sterile gauze and the entire limb encased in a skin-tight plaster-of-Paris splint. This method gives complete fixation and immobilization; thus by the principle of rest it gives the maximum opportunity for repair. This immobilization helps to localize the disease by eliminating muscular movement. Although the wound itself is full of organisms which have multiplied after the most extensive and careful debridgement, yet by encasing the limb in plaster they appear greatly inhibited as regards toxicity. It has been suggested that the calcium in the plaster plays some part in this, as immobilizing the limb in plaster, with a window cut out over the wound, gives less satisfactory results. Courage and clinical judgment are necessary in this form of treatment, as there is usually a pyrexial period of varying time and severity; the temperature may rise to 104°, but should be normal in four days. Once the plaster has been applied only the gravest reasons should cause it to be removed. In the majority of cases the pus that forms locally drains along the gauze in the wound, and soaks into the plaster. As a result the smell becomes very bad, and the first plaster usually needs changing in the third week. This must be done with great care, the limb being kept immobile during the process and another plaster immediately applied. A third plaster may be necessary. The earlier the treatment is carried out the better the results. Every effort should be made to do this within six hours.

III. **Punctured Wounds and Stabs.**—These may be brought about by any form of penetrating instrument, from a pin or needle to a sword, bayonet, or pickaxe. The external opening may be in itself insignificant, the chief danger arising from the damage to deep structures—blood-vessels or nerves being divided, and serous cavities or viscera opened, or even the skull penetrated. The subsequent symptoms depend almost entirely upon the question of infection; there is always considerable difficulty in draining effectively the depths of a long and narrow wound, and therefore collections of pus readily form and may burrow in all directions amongst the deeper planes of tissue opened up by the wound.

Wounds resulting from the modern **sword-bayonet,** though very serious from their size and depth, are not so difficult to heal as those inflicted by the old triangular blade. They should be effectively purified, well drained, and the skin opening not allowed to close until all discharge has ceased; if necessary, a counter-opening is made at a dependent spot. Serious hæmorrhage or paralysis calls for immediate opening up of the wound, so as to expose and deal with injured vessels or nerves.

Needles are frequently broken off short in the body, especially in the hands, feet, knees, or nates. If seen soon after the injury, it is advisable to undertake their immediate removal, a proceeding sometimes very simple, but occasionally necessitating a deep and difficult

dissection. Should the needle not be removed, it may travel about the body along the muscular and fascial planes, and there is no knowing where it may lodge or come to the surface, or how long it may remain in the body; it has been known to constitute the nucleus of a renal calculus.

One of the most troublesome and painful forms of penetrating wound is that caused by a **fish-hook,** since the barbed end catches in the tissues, and it is impossible to withdraw it without increasing the size of the wound considerably. The simplest plan of treatment is to push on the hook and make it protrude through the skin elsewhere to such an extent as to enable the barb to be cut away, when the remainder of the hook will be set free.

For the detection of penetrating foreign bodies of a metallic nature, or of splinters of glass or stone, radiography is indispensable. It is always necessary to take the radiograph from two directions, and if the antero-posterior one is taken stereoscopically, so much the better.

IV. **Poisoned Wounds.**—The great majority of poisoned wounds are due to some definite micro-organism, and have been discussed elsewhere. A few only remain to be dealt with here.

Stings of Insects, such as bees and wasps, are exceedingly painful, but not dangerous, unless some local complication, such as erysipelas, supervenes, or the stings are very numerous, as when a swarm of angry bees settles on a person, or the part involved is such as to lead to serious swelling, as in the pharynx or tongue, œdema of the glottis possibly arising under such circumstances. All that is usually needed is the application of a weak alkaline lotion, whilst a common and efficient domestic remedy is a freshly sliced onion or a blue-bag applied to the part.

Some varieties of flies and spiders are also extremely virulent, and the former play an active part in the transmission of many types of disease. Thus various forms of infective cellulitis or lymphangitis may be caused by the bite of a fly that has been feeding on putrid carrion, whilst the epidemic diarrhœa of children in summer is largely due to the infection of their food by flies.

The **black widow spider** (*Latrodectus mactans*) is the only proved variety of poison spider found in the United States. It is found throughout the south and the south-west, from the Atlantic to the Pacific. The *Latrodectus mactans* is not more than 1 to 1·5 cm. in length, shiny black in colour, and usually has red or orange markings on the ventral surface of the abdomen, the female having often an hour-glass-shaped bright red spot. This spider is found in brush, under stones and roots of dead trees, in country toilets and in dark places generally. The bite may be received at any time, even during sleep, and on any part of the body, and it may or may not leave a visible wound. Usually, however, shortly following the injury, the spot is marked as a fine red point on the skin. Within fifteen to thirty minutes after having been bitten, the victim complains of pain, usually in the region of the nearest lymph glands and, within an hour or so, of pain in the chest or abdomen. The temperature rises, the leucocyte count goes up, the abdomen becomes rigid, and the patient may have a chill. There may be nausea, vomiting, cyanosis, speech disturbance,

urine retention, coma, shock, and sometimes jaundice has been seen. There is often collapse, cold clammy sweat, and the patient is seriously ill. The pulse is at first accelerated, but usually soon becomes slow. The blood-pressure in the beginning is raised, as is also the cerebro-spinal fluid pressure. This, too, presently (after twenty-four hours) returns to normal. The condition has been mistaken for appendicitis, cases even having been operated upon. The diagnosis of meningitis has also been made. *The fact that all other muscles as well as those* of the abdomen are rigid or spastic should serve to make one think of the possibility of spider bite.

The **Treatment** is symptomatic. There is no need for incisions, etc. The poison is already disseminated before the doctor sees the patient. Hot baths are useful, and 10 per cent. magnesium sulphate intravenously has been used. Hot fomentations to the abdomen are grateful, and it may be necessary to administer morphine several times to relieve the 'cramps' in the abdomen. Convalescent serum has been given and is said to work well.

Snake-bites are exceedingly rare in this country, the common adder (*Pelias berus*) being the only venomous one likely to be met with, and even with this the poison is not sufficiently virulent to do much harm unless the individual attacked is a child or a person in a very bad state of health. The poison is conveyed to the wound from the glands and poison sac situated on either side of the upper jaw through fine canals in the specialized teeth, which open at their apices; these teeth are so delicate in some snakes that it may be difficult to find the wounds produced by them, but as a rule a double puncture is seen. The effects of an adder's bite are not, as a rule, noticed immediately, but come on in the course of an hour or so; extreme prostration supervenes, with a weak pulse, cold clammy perspiration, dilatation of the pupils, and perhaps delirium in bad cases, merging into coma.

The **Treatment** consists in preventing the absorption of the virus by tying a ligature firmly above the wound, which should then be laid open so as to allow of free bleeding, and the surface excised or cauterized. The collapse resulting from absorption of the poison is best remedied by the administration of stimulants or the hypodermic injection of strychnine.

Bites from the rattlesnake and the copper-head (pit vipers) are encountered throughout the United States and in some parts of Canada. In the southern and middle States the moccasin (cotton-mouth, also a pit viper) is encountered. Near the Gulf Coast is found a small and less deadly snake, the coral snake.

Bites by any of these in children are very dangerous, and the bites of the rattlesnake, copper-head, or moccasin are dangerous to adults as well. The larger the snake, the more venom injected. For the treatment of these, use of antivenene has almost entirely replaced all other treatment. A polyvalent antivenene is for sale at all drug stores during the snake season. An institute for its manufacture is maintained at Pittsburgh, Pa.

The **Anatomical Tubercle**, or **Butcher's Wart** (*Verruca necrogenica*), consists in a papillomatous development, usually on the knuckles or

wrists, of those who are exposed to wounds either in the dead-house or slaughter-house. It is in all probability a manifestation of tuberculous infection, and, indeed, resembles somewhat closely the appearance of lupus when it develops on the hands. Treatment consists in the application of a powerful caustic, whilst in bad cases it is necessary to scrape the surface before cauterizing.

Poisoned Wounds of the Fingers are not uncommon, arising from the infection of pricks, scratches, and abrasions, and sometimes giving rise to serious consequences, and especially when the patient's occupation brings his hands into contact with infective material. The dissecting-room used to be a fertile source of poisoned fingers, but the care now taken in the preparation of the cadaver has almost abolished this form of trouble.

Undoubtedly the most serious of these arise in the post-mortem room, and are very largely due to carelessness and over-confidence. They may follow knife-cuts, or needle-pricks, or scratches from the exposed ragged ends of the ribs, and the infection is usually due to the *Streptococcus hæmolyticus*. Too often no heed is given to the wound except a more or less casual wash after the post-mortem is over. In a day or two, however, the finger and arm may be swollen and painful, and the axilla may even be involved, whilst grave constitutional disturbance of a septicæmic character may cause death in a few days. Not a few promising young pathologists and surgeons have lost their lives in this way. **Treatment.**—It is essential in cases of this type that the most thorough precautions be taken at once, seeing that life itself is at stake. If practicable the investigation or operation should be concluded by someone else, and the wound exposed and cared for. The parts are thoroughly cleansed with ether soap, etc., and bleeding encouraged; if need be, an elastic compress is placed around the arm so as to ensure abundant venous bleeding for two or three minutes. The finger is then immersed in tincture of iodine for five minutes, care being taken to ensure its admittance to all parts of the wound. A comfortable sterile dressing is applied, and the arm put to rest and kept quiet until the outcome is assured.

Should infection occur, it may be limited to the nail matrix or pulp of the finger, or it may involve the tendon sheaths or palmar fascial interspaces, or in the worst cases it may become a rapidly spreading lymphangitis, running up the arm into the axilla in a few hours, and possibly flooding the system with germs. Most of these conditions are described elsewhere, as also the appropriate treatment, but it may be well to deal with the localized infections of the hand known as whitlow at this place.

Whitlow is the term applied popularly to an infected wound of a finger or hand which is extremely painful, and usually runs on to suppuration. It is sometimes limited to the finger, but not unfrequently spreads to the palm or even to the forearm along the tendons and their sheaths, or along the fascial spaces of the palm. Several varieties may be recognized, and it is most important that a clear diagnosis should be made before any treatment by operation is undertaken.

(*a*) The **Subcuticular** whitlow (or purulent blister) consists merely in the development beneath the cuticle of pus which separates it from the cutis vera. It is painful, but otherwise of little importance. A boric fomentation, preceded by the removal of the loose cuticle, is all that is needed in its treatment.

(*b*) Infection of the *cellular tissue* of the fingers is extremely liable to involve the underlying tendon sheaths, except when it is limited to the *terminal segment*, and in this paragraph that limited portion will be alone alluded to. Under these circumstances the end of the finger becomes bulbous and extremely tender, the swelling extending perhaps some way up the finger, but there is no painful limitation of flexion or extension. The swelling is at first hard and brawny, and even when pus is present it may be difficult to detect fluctuation unless the abscess is nearly pointing. Constitutional symptoms are not as a rule very severe, although the pain may exhaust the patient, being greatly increased by allowing the hand to hang down.

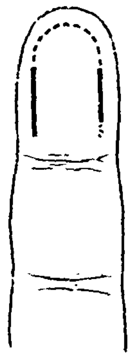


FIG. 98.—INCISIONS FOR WHITLOW LIMITED TO TERMINAL PHALANX.

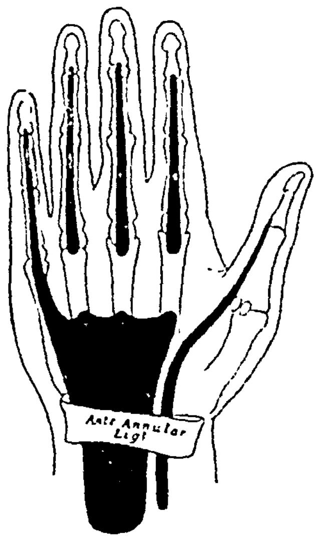


FIG. 99.—DIAGRAM OF TENDON SHEATHS OF FINGERS AND PALM.

Treatment.—This must be by early incision, which may be on one or both sides of the terminal phalanx, never in the mid-line (Fig. 98). The incisions should not be joined by a transverse distal one, as this tends to produce a tender scar on the exposed pulp of the finger. The blood-supply of the distal phalanx is easily occluded owing to swelling in the fibrous septa of the pulp. Fluctuation must not be waited for, but an incision should be made as soon as the patient complains of a painful swollen terminal phalanx. Failure to incise leads to necrosis of the terminal phalanx due to lack of blood-supply, with subsequent sequestrum formation, a grave disability in a musician.

(*c*) The **Thecal** form of whitlow is in reality a suppurative tenosynovitis of the flexor sheaths, and the infection is very liable to spread from them into the palm and even to the forearm. The arrangement of these sheaths is indicated in Fig. 99, and it will be

obvious that the thumb and little finger are more likely to be affected in this way than the other fingers, and the thumb more often than the little finger, as there is a slight break in the continuity of the little finger sheath which, however, is readily overstepped. The sheaths of the index, middle, and ring fingers are liable to give way at their proximal end, and then an inflammatory affection of the palmar fascial spaces will subsequently develop, and this may in turn extend to the forearm under the annular ligament.

In a whitlow of this type the finger becomes generally swollen, both in front and behind; it is slightly flexed, and the patient is quite unable to move it, because of the severe pain caused thereby; any attempt at extension is exquisitely painful, and acute tenderness is present over the whole course of the sheath. The swelling is at first of a brawny character, and even when pus is present fluctuation is rarely to be detected, except when it is actually pointing. Sometimes the pus points towards the dorsal aspect of the finger, owing to yielding of weak spots in the postero-lateral aspects of the sheath. The intercarpal articulations may be secondarily involved, and necrosis or caries of the phalanges may follow. There is always a good deal of febrile disturbance of a septic type, and want of sleep from the pain is distressing. Unless early relief of tension is given, the tendons are very likely to slough, or at best to contract such adhesions to the underlying bone or sheath as will render the finger useless.

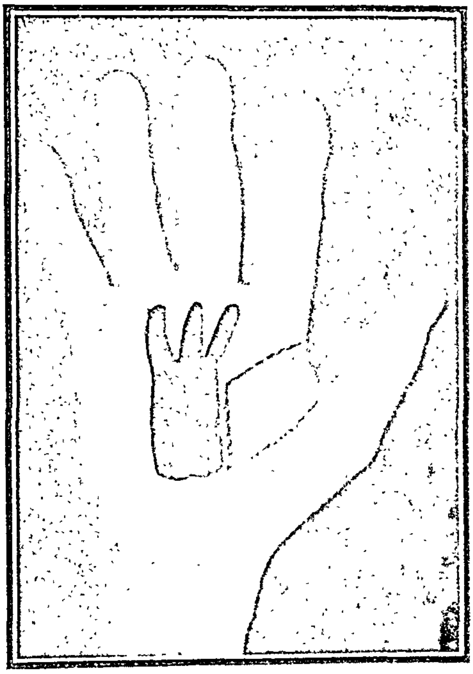


Fig. 100. — Diagram showing the Position of the Thenar and Middle Palmar Fascial Spaces.

Extension to the *palmar bursæ* in lesions of the thumb and little finger is indicated by the palm becoming swollen, although the tension of the palmar fascia prevents this from being marked. The part is very tender and the pain severe (Fig. 100). Unless relief to tension is given early, the trouble is almost certain to spread under the anterior annular ligament to the forearm, and do much mischief. Sloughing of the tendons is very likely to follow, or crippling adhesions to form (Fig. 101).

Extension to the *palmar fascial spaces* from the three middle fingers is indicated by much the same symptoms, and may be followed by very similar results. If the trouble spreads upwards to the forearm, it usually finds its way beneath the tendons, and thus appears in the arm between the pronator quadratus and the tendons of the flexor profundus. The thenar space should be drained by an

incision on the dorsum of the hand, as shown in Fig. 102. The incision is made on the radial side of the metacarpal bone of the index finger.

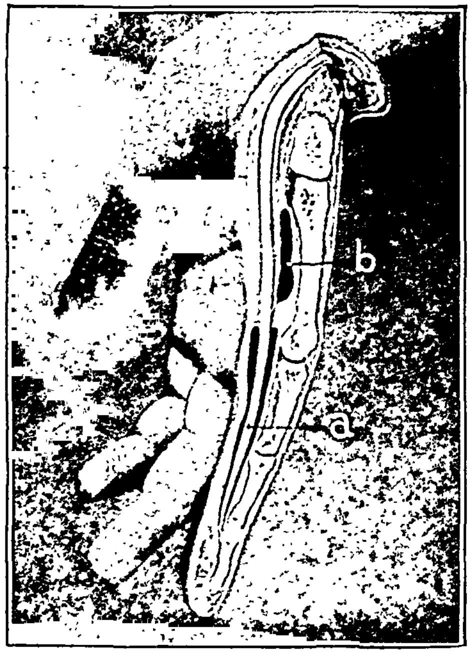


FIG. 101.—RELATION OF THE TENDON SHEATH OF THE RING FINGER. (A. B. KANAVEL.)

a, To the middle palmar space; b, this demonstrates the ease with which extension of pus from the tendon sheath may take place into the middle palmar space.

Lymphatic infection may be associated with any of these manifestations in the form either of an acute lymphangitis or acute inflammation of the epicondyloid or axillary glands, in the latter instance being perhaps followed by an axillary cellulitis. Naturally the constitutional results will be greatly increased by these complications.

Treatment in the early stages consists of rest to the arm, which is supported, fomentations, and passive congestion. As soon as it is evident that pus is forming or has formed, operative measures must be undertaken in order to try to limit the mischief. Incisions on one or both sides of the finger are required to lay open the sheath (Fig. 103), and thereby to prevent as far as possible the formation of adhesions and to prevent sloughing. It may suffice to limit the incisions to the inter-articular segments of the finger, but in bad cases the whole length of the sheath must be laid open.

FIG. 102.—INCISIONS FOR DRAINING THENAR SPACES.

Showing incisions which should be made upon the dorsum of the hand. That upon the thenar space is made to drain the thenar space in the palm. Those upon the distal part are made to drain extensions from the palmar space to the dorsum.

In the case of the little finger, extension to the ulnar bursa may be suspected if there is acute tenderness along its course; and if after opening the sheath pressure in the palm causes a discharge of pus, this complication is assured. A director or bent probe is then passed up the sheath, and cut down on through an incision on the

radial side of the hypothenar eminence (Fig. 103), and thus the sheath is again opened freely. No drainage-tube is permissible in these cases, as they only lead to sloughing. If it is necessary to keep the opening in the sheath patent, a strip of rubber glove possibly rolled into a spill must be used.

Similar treatment is required for infection of the palmar bursa, and the necessary incision is shown in Fig. 103.

Infection of the fascial spaces of the palm in whitlows of the middle three fingers is similarly dealt with by suitable incisions. The chief space lies in front of the metacarpal bones of these fingers, and can be reached by an incision extending from the centre of the web to midway between the distal and central flexion creases in the palm (Fig. 103). The incision is best placed on the side of the ring finger, and should extend down to the lumbrical muscle. Drainage is maintained by a strip of rubber glove. The thenar space can be reached for drainage purposes by an incision along the side of the index metacarpal (Fig. 102) which exposes the lower border of the adductor, and in front of this an artery forceps can be introduced so as to reach the collection of pus.

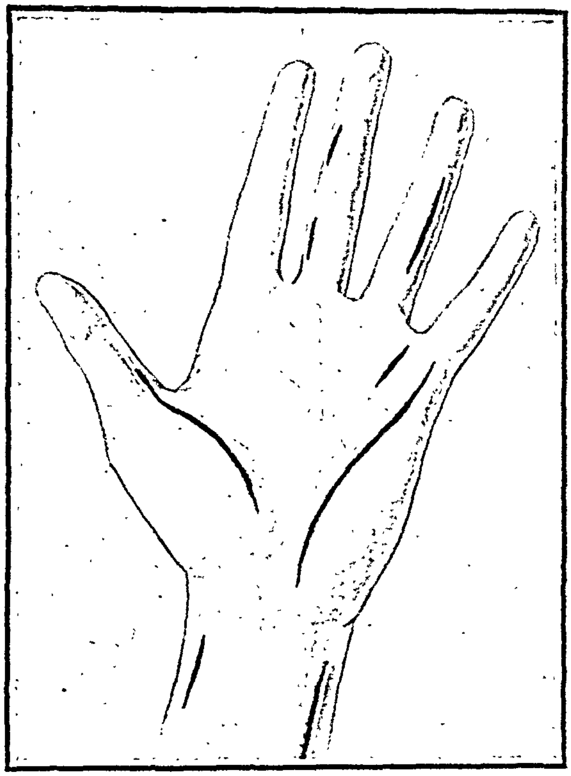


Fig. 103.—Incisions for dealing with Various Forms of Whitlow and their Extensions to Hand and Forearm.

It must be remembered that infections of the palm similar in type to the above may arise quite independently of whitlows as a result of direct infection through penetrating wounds.

If the mischief spreads under the annular ligament and suppuration occurs in the forearm, incisions are made on either side (Fig. 103), so as to enable a pair of sinus forceps to be passed down in front of the pronator quadratus, where the pus is likely to be found. Drainage is here maintained, as elsewhere, by a strip of rubber glove and not by a drainage-tube. The all-important element in the case is absolute freedom from tension by large incisions.

After the incisions have been made, fomentations are maintained as long as there is any appreciable discharge of pus. Baths are useful, and later packing with gauze soaked in flavine or other applications is desirable as a dressing.

Repair of Wounds.

When any of the tissues or solid organs have been divided or injured, the reparative activities of the body early assert themselves in order to make good the defect, unless they are for a time diverted by the necessity of overcoming an invasion of bacteria, and even then the means employed by Nature to conquer the microbes are useful in determining the early stages of repair. It matters little what tissue of the body is involved, for the reparative process is the same in all, although modified somewhat by the local conditions. In the majority of cases the ultimate result is a production of cicatricial or scar tissue, which serves as the bond of union between the divided structures, and varies in amount with the closeness of approximation, the maintenance or not of rest to the part, and the degree of inflammatory disturbance in the wound.

In a few tissues a further stage, *viz.* that of *regeneration* of the injured parts, is reached; in this there is a preliminary formation of granulation tissue, which is subsequently invaded and replaced by a development from the parenchyma of the affected tissue or organ, but this can only occur when the parts are accurately brought together and perfect asepsis is present. Striped muscle, bone, tendon, nerves, and some glandular structures may thus be regenerated; the skin and subcutaneous tissues, rarely; the spinal cord, never.

The **general facts as to the process of repair** may be stated as follows: The margins of the wound are always bounded by an area of tissue in a state of lowered vitality, even if no bruising or sloughing of the parts is present. The divided vessels are in a condition of thrombosis as far as the next patent branches, which in their turn are slightly dilated, partly as a result of this obstruction and partly from the reflex irritation of the injury. The surface of the wound is generally covered with a film of lymph or blood-clot, whilst any spaces left in the interstices of the tissues are similarly occupied.

1. **Healing by First Intention,** or **Primary Union,** occurs in cleanly-cut aseptic wounds where the lips are unbruised and brought together, so that no extensive collection of blood or discharge between them is possible. A thin layer of blood-clot lies between the surfaces of the wound and penetrates into their irregularities, and the contraction of this clot is at first the chief means of keeping the deeper parts in apposition. There is but a microscopic line of damaged tissue, which, together with the blood-clot, is easily absorbed. A thin layer of granulations develops on either side (Fig. 104), and these unite across the wound in a few days and are transformed into granulation tissue.

2. **Healing by Granulation,** or **Second Intention,** as it used to be termed, is met with (*a*) in cases where there has been definite loss of substance, so that the lips of the wound are not, or cannot be, approximated; as also (*b*) when the surface of the wound is bruised or damaged, so that portions of tissue have to separate by sloughing; or (*c*) when the advent of infection has prevented the occurrence of primary union.

When a small amount of aseptic dead tissue is present, it is removed by an invasion of leucocytes from the surrounding vessels, which

disintegrate and gradually absorb it. These are followed by the fibroblasts, which form a layer of granulation tissue on the surface of the wound. If there is much slough to be dealt with, the vitality of the granulation tissue cannot be maintained beyond a certain distance from its source of nutrition, and so by a process of simple anæmic ulceration the unabsorbed dead portion is cast off and a granulating surface remains. If bacteria are present in the slough, inflammation occurs in the adjacent living tissue, and this brings about a similar result, though accompanied by suppuration and fever.

When, however, there is a simple loss of substance, with no bruising or infection of the tissues, the course of events is as follows: The blood-stream in the superficial capillaries having been arrested, adjacent vessels become dilated, and from these an exudation of plasma and leucocytes results. The plasma coagulates on the surface and forms a layer of fibrin, entangled in the meshes of which are a number of white corpuscles, so that the wound becomes covered with a film of whitish-yellow material known as coagulated lymph. This gradually increases in amount and thickness, and is vascularized from below into granulation tissue, this process occupying from four to seven days.

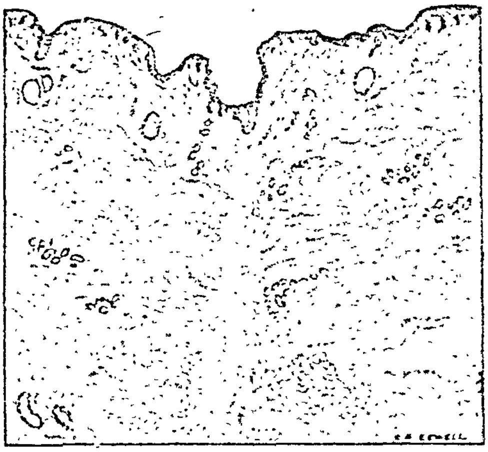


FIG. 104.—HEALING OF WOUND BY FIRST INTENTION.

The healing of a granulating wound is brought about by the conversion of the granulations into fibro-cicatricial tissue, and by the surface becoming covered with cuticle. The contractile tendency inherent in all cicatricial tissue produces two results from its presence in the base of the wound beneath the superficial layer of granulations: (i.) The surface area of the wound is diminished in all directions, a most important element in the healing process, since if the base is adherent to some dense resisting structure repair is slow and difficult. When the granulating surface is very extensive, contraction may proceed to such a degree as to obliterate many of the vascular channels, and by thus depriving the superficial tissues of their adequate nutrition, the healing process may be indefinitely prolonged. (ii.) The depth of the wound is diminished, partly by the continuous growth of granulation tissue from below upwards, but mainly by the contractile base lifting the deeper structures to the surface. If the base of the wound cannot be raised, the superficial parts are drawn down, and the cicatrix is usually depressed and adherent to the underlying parts.

3. **Healing under a Scab** is a proceeding that can only take place in very small wounds, such as superficial grazes and abrasions, and is practically identical with the granulating process, except that,

instead of an artificial dressing applied by the surgeon, the lesion is covered by a scab which consists of clotted blood or dried exudation. Should infection be present, pus is likely to accumulate beneath the scab and may cause trouble.

4. **Healing by Organization of Blood-clot** can only be watched in strictly aseptic wounds where there is definite loss of substance, as in the deep channels sometimes made in the treatment of bones thickened by chronic osteitis, but of course it occurs in all subcutaneous wounds where there is effusion of blood. The dark coagulum shows no trace of change for some days, but gradually the peripheral portions become granular and yellowish-white in colour; granulations appear in this peripheral portion, and in time spread through the whole mass from periphery to centre, and then repair occurs as described above. The clot is absolutely passive in this process, being infiltrated by leucocytes and removed by degrees, and thus merely serves as a basis of support or scaffolding for the building up of the granulation tissue which replaces it.

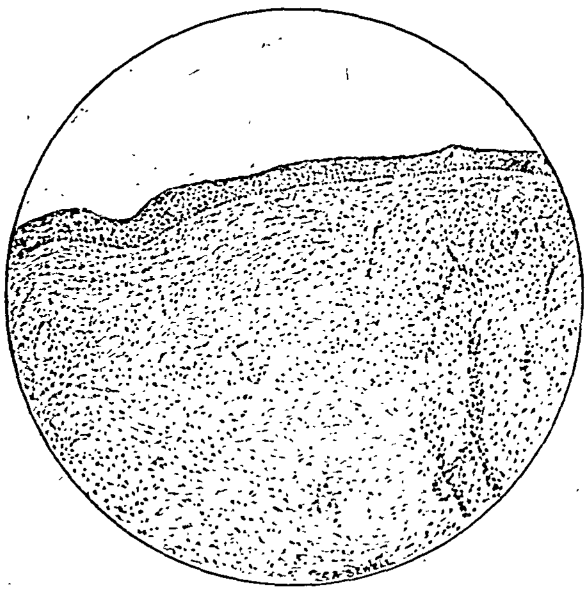


FIG. 105.—SCAR FROM A RECENTLY HEALED SUPERFICIAL WOUND. (LOW POWER.)

The epithelial surface is regular and devoid of papillæ; the scar tissue has an abundance of cells scattered through it, as well as some very obvious vessels, which will disappear almost entirely at a later date.

5. **Healing of a Detached Portion of the Body** is not unfrequently seen when parts of the nose, external ear, or finger-tip are separated. The loose portion is carefully cleansed, reapplied accurately, and fixed firmly, though gently, into position. If it lives, union occurs by first intention; if it dies, but remains aseptic, it constitutes a cover or scab, under which healing by granulation occurs.

A **Scar** is a mass of fibroid tissue covered by epithelium, which has been formed in the repair of a wound (Fig. 105). It is at first vascular, and contains cells of the connective-tissue type; but after a time, as contraction continues, the cell elements become flattened out, fewer in number and less obvious, the intercellular fibrous tissue more abundant, and the vessels constricted, so that finally a scar becomes well-nigh bloodless. Where superficial, its colour changes from red to white, and if of small size it may almost disappear, but never abso-

lutely, unless the subcutaneous tissue has not been involved. When the parts around become infected by any cause, such as sharp friction, the anæmic scar tissue again becomes evident by contrast. Lymphatics, nerves, hairs, and cutaneous glands are all absent, except perhaps at the periphery, and the epithelial covering itself is merely a uniform layer without papillæ.

The **Pathological Phenomena** connected with scars are as follows:

1. **Excessive Contraction,** which may lead to great deformity, especially when the wound has occurred in the flexure of any of the joints. A web-like mass of fibroid tissue then forms, limiting movement, and requiring operative interference. A seriously burned hand may by cicatricial contraction be fused into an unsightly mass, rendering the fingers of little use; similarly, the chin may be drawn down and practically fixed to the sternum, and the lower lip everted, as the result of a burn on the front of the neck (Fig. 106). The *Treatment* of such conditions consists in dividing or excising the cicatrix, and thus freeing the parts, during which process it must be remembered that deeper structures of importance, such as the main vessels and nerves, may be adherent to the under surface, and thus be endangered. When once the scar has been divided, there is often no difficulty in restoring the parts to their normal positions, although when the contraction has existed for any length of time it may be advisable to do this slowly, even by gradual extension with a weight and pulley, so as to avoid the risk of lacerating the deeper parts, which are usually contracted secondarily. The raw surface thus produced is covered with epithelium by Thiersch's method or Wolfe grafts, or by turning in a flap.

FIG. 106.—CICATRICIAL CONTRACTION OF NECK AND FACE AFTER A BURN.

A similar process of contraction takes place in scars developing deeply amongst the tissues, or in connection with the viscera. Various deformities result from undue contraction after suppurative myositis or after the intrinsic development of scar tissue in muscles, *e.g.* torticollis, and this possibility must always be kept in mind during treatment. Grave disability may follow the healing of a wound opening up deep planes of tissue, unless precautions are adopted to prevent subsequent contraction. Thus after clearing the axilla in operations for scirrhus mammæ, abduction is likely to be limited unless the arm is kept in a position of full abduction during healing. The contraction of scars in visceral lesions is also a matter of grave significance, and we shall allude later to various complications arising therefrom, *e.g.* hour-glass stomach, stenosis of the pylorus, etc.

2. **Adherent Scars** are often troublesome and painful, especially when the adhesions involve muscular tissues. Whenever the parts con-

trolled by the affected muscles are moved, the scar is dragged on and pain results. Thus a scar involving the substance of the tibialis anticus and adherent to the overlying skin is dragged on in all movements of the foot, and walking may become difficult or impossible on account of the pain. In such cases the freeing of the scar from the skin may be desirable; the superficial portion of the scar is dissected out and the skin and subcutaneous tissues around are freed and drawn over the deeper part from either side. Scars adherent to bones are difficult to deal with and may be very crippling in their results, *e.g.* when the quadriceps is firmly fixed to the front of the femur the movements of the knee are gravely impaired. Massage and movements (active, passive, or forcible) may suffice to free the limb, but it is probable that operative treatment is justifiable in some cases.

3. **Overgrowth of the Scar Tissue** is sometimes met with, constituting what is known as the false or **Alibert's Keloid.** This most frequently

FIG. 107.—KELOID FOLLOWING OPERATION FOR GLANDS IN THE NECK.

occurs in the scars of burns or of wounds in tuberculous patients, but may arise from any cicatrix, presenting itself as a fibroid indurated mass of a dusky red colour, with perhaps a number of dilated vessels coursing over it, which occupies the region of the old scar, and may possibly send claw-like processes into neighbouring healthy structures. It consists merely of a hyperplasia of the scar tissue, but as to its ætiology nothing is known. With the exception of somewhat severe pruritus or itching, its presence entails no inconvenience, although if it occurs on exposed parts it may be very disfiguring (Fig. 107). Removal is useless, since the keloid almost always recurs in the new cicatrix and in the stitch holes. After a longer or shorter interval it often disappears spontaneously. Exposure to X-rays or to radium is very beneficial in these cases.

4. **Ulceration of Scars** is usually an evidence of defective nutrition, or of local irritation. It is always chronic and difficult to heal. Local

protection and stimulating applications, together with general tonic treatment, are required.

5. **Painful Scars** arise from either the implication of a nerve terminal in the cicatrix, or the pressure of a contracting scar upon the bulbous end of a divided nerve, as in amputation stumps. The pain is often very persistent and wearing, and may radiate widely. Treatment consists in freeing the nerve from the scar tissue (p. 384), or in its excision.

6. **Malignant Disease of Scars,** or of old chronic sores but partially healed, is of an epitheliomatous type, and appears as a hard ulcerated tumour with everted edges and a thickened base (*Marjolin's ulcer*). The progress is very slow, since the vascularity of the tissue is slight. It is painless from the absence of nerves, and as long as the disease is limited to the scar no lymphatic implication will be noted.

CHAPTER IX.

HÆMORRHAGE AND SHOCK.

By the term *hæmorrhage* is meant any escape of blood from the vessels, whether insignificant and immediately arrested by natural means, or more excessive and requiring treatment to prevent its continuance. Although most commonly due to traumatism, it may occur in certain diseases, such as purpura and scurvy; whilst in hæmophilia there is a congenital lack of coagulable power, so that it is difficult to stop any flow of blood when started.

Arterial Hæmorrhage consists in a flow of bright red blood, which at first escapes in jets, pulsating synchronously with the heart's beat. It is derived not only from the proximal, but also from the distal end of the divided vessel, if the collateral circulation is sufficiently abundant. If, however, it is derived from a deep artery the blood may well up from the depths of the wound and not escape in gushes. In **Venous Hæmorrhage** the flow is usually continuous, and the blood of a dark red or almost black colour. If, however, a large vein is wounded, such as the internal jugular, the blood may escape with a very definite spurt, owing to respiratory or other influences. **Capillary Hæmorrhage** is marked by general oozing from a raw surface, the blood trickling down into a wound, if present, and filling it from below upwards. By **Extravasation of Blood** is meant an effusion of blood from a wounded vessel or vessels, into the lax areolar planes immediately adjacent, which become swollen and boggy, resulting in the formation of a hæmatoma. The usual constitutional signs are manifested in the cases of a large extravasation, and fatal hæmorrhage may even occur in this way without any escape upon the surface of the body, particularly in the case of bleeding into the serous cavities. Subcutaneous or submucous hæmorrhage is also met with in the form of small localized petechiæ, arising from injuries or from changes in the blood or vessel walls (as in purpura, scurvy, and septicæmia). **Epistaxis** is the term given to bleeding from the nose. By **Hæmatemesis** is meant the vomiting of blood. It usually originates from the stomach, duodenum, or lower end of œsophagus, but may have been swallowed in the case of epistaxis. If it has remained in the stomach any length of time, the blood becomes curdled and brownish in colour, somewhat resembling coffee-grounds, from the action of the gastric juice. When gastric hæmorrhage is more active, the blood is bright red in colour, and may be vomited in the form of large clots. **Hæmoptysis** is the escape of blood from the air passages, whether it results from injury or disease. In the milder cases it is usually bright red and frothy from admixture with air; in graver cases, when larger

vessels are involved, the blood may escape unaltered, and be so abundant as to asphyxiate the patient. **Hæmaturia** (*q.v.*) is a condition in which blood is passed in the urine. By **Melæna** is meant the passage of dark tarry blood with the fæces; it is always an evidence of disease or injury of the intestinal canal sufficiently far from the anus to allow the blood to become altered in character by the action of the intestinal juices. Blood derived from the rectal mucous membrane usually retains its bright red colour.

The Clinical Features of Hæmorrhage.—The effects of hæmorrhage fall into two groups, local and constitutional. The **local** features consist of either the escape of blood when there is an open wound or the formation of a hæmatoma when the hæmorrhage is internal. In most cases when the bleeding site is accessible to palpation a swelling will become evident which is boggy at first, and later, if the bleeding continues, may become tense. At other times the bleeding may be internal and concealed, as for instance with an intra-peritoneal hæmorrhage, in which case it may be possible to detect the presence of shifting dulness in the flanks and possibly signs of peritoneal irritation; but sometimes there will be no localizing features at all.

The Constitutional Effects of hæmorrhage are twofold: (1) There is a loss of the fluid content of the blood, but this is readily and rapidly made good within certain limits by the withdrawal of tissue fluid. The blood-pressure falls, but unless the loss is great it quickly rises to the normal after the bleeding has ceased; this restoration is due partly to a diminution of the vascular area, owing to vasomotor contraction of the peripheral arterioles, but also to the rapid absorption of the tissue fluid already mentioned. In severe cases, especially when shock is superadded, the blood-pressure may remain low. (2) An even more important loss is that of the red cells with their oxygen-carrying hæmoglobin; hence after a severe hæmorrhage the supply of oxygen to the tissues is defective, and this may be of serious import in cases of shock. For the changes that occur in the blood as a result of hæmorrhage see p. 28.

If the hæmorrhage is severe, as from division of a large artery, death may result from syncope. The surface of the body becomes cold, clammy, and pale; the lips, ears, and eyelids are livid; the patient gasps, his respirations become quick and sighing, and death ensues after perhaps a few convulsive twitches of the limbs.

If the hæmorrhage is less severe, the patient faints, and on recovery is in a condition of severe collapse and weakness, which continues for some time; he is also liable to recurrent attacks of syncope, especially if the bleeding persists.

When the hæmorrhage is *concealed* and of moderate severity, as from ulceration of the stomach or duodenum, or by slipping of a ligature after an abdominal operation, the patient rapidly becomes profoundly anæmic, and his face shrunken and drawn as a result of the dehydration of the tissues of the cheeks. The organs of the body generally suffer from want of oxygen, and hence the patient feels as if he were being suffocated, and is extremely restless, tossing about in bed, and clamouring for open windows and more air (*air-hunger*).

Any sudden exertion, or even sometimes the attempt to sit up, is followed by a sensation of faintness or actual syncope; noises are heard in the ears, the sight becomes dim, or is even temporarily lost (amblyopia), and severe headache may be complained of, all arising from cerebral anæmia. The pulse often becomes what is known as *hæmorrhagic* in character, *i.e.* frequent and compressible, but collapsing entirely between the beats, and markedly dicrotic; this is due to the sudden passage of a small amount of blood through a vessel which is practically empty.

Natural Arrest of Hæmorrhage.—This process, which applies in all types of bleeding, whether arterial, venous, or capillary, is accomplished in the following manner:

The **Temporary** arrest of arterial hæmorrhage is brought about by three principal factors:

(1) **The coagulation of the blood,** which occurs in and around the vessel, and without which death would ensue from the merest scratch. The coagulability of the blood varies in different subjects, and is influenced by various conditions, *e.g.* the amount of calcium salts present. In hæmophilia the blood coagulates with difficulty, and therefore hæmorrhage is always a serious phenomenon. Loss of blood increases the coagulability to a certain degree.

(2) **Diminution in the force of the heart's action** always follows hæmorrhage from anæmia of the cerebral centres, and thereby coagulation is facilitated and the flow of blood checked.

(3) **Changes in and around the vessel** play a most important part in completing the process. They consist in the **retraction** of the artery within its sheath by reason of its inherent longitudinal elasticity; if, however, it is only divided partially (or, as it is called, ' button-holed '), this condition cannot obtain and the hæmorrhage is more likely to continue. As a result of this retraction, the rough and uneven inner lining of the sheath is exposed, and upon this the blood coagulates as it flows, thus gradually producing what is known as the **external coagulum.** At the same time the transverse muscular and elastic fibres in the vessel wall cause **contraction** of the open mouth, and thereby the external coagulum is able to increase in size by fresh deposits of fibrin, until at last its resistance is too great for the diminished cardiac impulse to overcome, and the sheath is filled with clot, which extends to the divided mouth of the vessel. From this an internal coagulum occasionally develops, extending upwards as far as the nearest patent branch.

The **Permanent** closure of the wound in the artery is brought about by a modification of the general process of repair. When the escape of blood has ceased, the arterial wall contracts upon any clot which may be present. As a result of the injury a simple arteritis is set up, evidenced by a hyperæmic condition of the vessel wall and its infiltration with leucocytes which also attack the coagulum, breaking it up and traversing the natural lines of cleavage which result from its contraction, and gradually remove it, a few giant-cells sometimes assisting in the process. The endothelial cells of the tunica intima proliferate, leading to a secondary infiltration of the thrombus with

large fibroblastic cells which, with the addition of capillaries derived from the vasa vasorum, convert the affected portion of the vessel wall into a rod of granulation tissue (Fig. 108), and this in due course is transformed into cicatricial tissue, which finally replaces the divided vessel. Similar changes occur in the distal end of an artery tied in its continuity. The ligature itself is infiltrated by leucocytes and absorbed, or it may be encapsuled. The presence of a coagulum is no essential element in this process, for if the arterial walls are merely drawn together by a ligature so as to be in apposition, a similar occlusion results.

The arrest of hæmorrhage from veins and capillaries is more easily accomplished, the collapse of the walls and the absence of blood-pressure facilitating the process. The later steps are similar to those occurring in an artery.

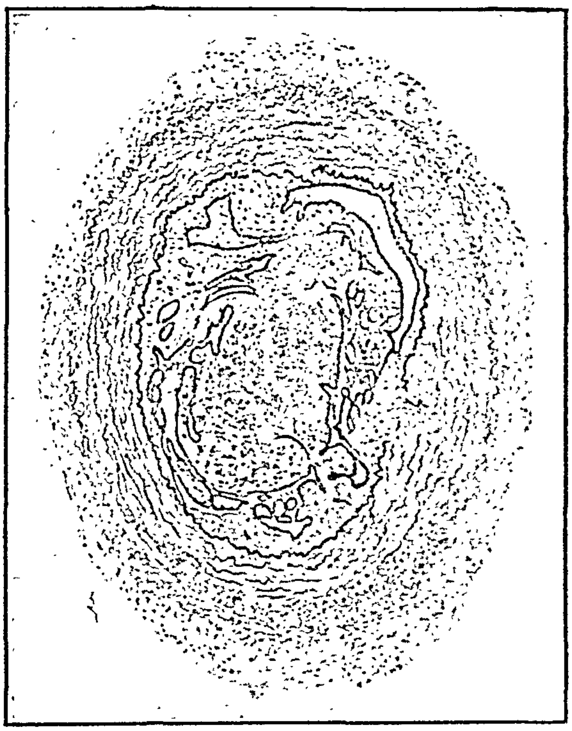


FIG. 108.—ORGANIZATION OF THROMBUS IN AN ARTERY.

The clot has become vascularized, and in parts is almost canalized. The thrombus has practically disappeared, and is replaced by granulation tissue undergoing organization; its origin from the tunica intima is clearly indicated.

Treatment of Hæmorrhage.

This consists in the adoption of measures which aim at the control of the hæmorrhage and a counteraction of the ill-effects. It may, therefore, be considered under local and general headings.

A. **Local Treatment of Hæmorrhage—Direct Pressure.**—It may be laid down as a preliminary axiom that if the bleeding point is accessible, digital pressure will check it, and must be maintained until other methods are available for dealing with the hæmorrhage. This will consist in the first instance of the application of a tourniquet on the proximal side of the bleeding point. This appliance consists of a constricting band placed around the limb with sufficient pressure to occlude the arterial flow. Usually a piece of rubber tubing, with some simple piece of mechanism attached to it to maintain a hold, is employed, but in cases of emergency a useful substitute can be fashioned out of a large handkerchief which is knotted loosely around the limb and tightened by the rotation of a piece of wood inserted beneath it. Compression over the main artery may be aided by the inclusion in the tourniquet of a pad placed over the vessel. It should be re-

membered that the use of a tourniquet must be for as short a period as possible, and only in extreme cases for a period longer than one hour, as serious devitalization of the tissues of the limb or some form of pressure neuritis may ensue. In other cases, when the bleeding proceeds from spaces or hollow cavities such as the nose or uterus, the flow can often be arrested by plugging with strips of sterilized gauze which may be left *in situ* for twenty-four hours. At the end of that time the bleeding has usually ceased, but if it recurs the wound should be replugged. When the bleeding consists of a general ooze from cut surfaces, it can often be checked by bringing the raw surfaces into apposition with each other.

B. **Operative Treatment of Hæmorrhage.**—This will be necessary if the bleeding has not ceased after the maintenance of digital compression or a tourniquet for an appropriate interval. The principle which is followed is the attainment of an exposure adequate enough to permit the bleeding point to be defined and controlled. It is often impossible to know the exact source of the hæmorrhage unless it is laid bare. Thus the bleeding from a punctured wound of the front of the leg, which was apparently derived from the anterior tibial artery, was proved on incision and careful dissection to come from the peroneal, the wound extending backwards between the bones. In the axilla and groin such uncertainty often exists.

It is often necessary to secure both ends of the wounded vessel, as the presence of collateral circulation will cause bleeding from the distal end.

The method used most frequently to-day is that of ligature. The material should be of sufficient strength to secure the vessel, of sufficient resistance to maintain its hold in spite of being soaked in the body fluids, and yet of such quality as to be absorbed, or so pure and unirritating as to become encapsuled in the tissues. *Catgut* suitably prepared is generally employed. It is obtained from sheep's intestines by allowing them to putrefy in water, and then scraping away the mucous and muscular coats, leaving only the elastic basement membrane of the submucosa; this is dried and twisted into the long strands of commercial catgut. When soaked in blood-serum this substance swells up into a soft, pulpy mass in half an hour, so that it is necessary to sterilize it thoroughly.

Sterilized silk and linen thread are also employed, but, not being absorbable, should be avoided in septic cases, as they are almost certain to slough out under such circumstances, and may cause much trouble.

The immediate *effect* of a ligature *on the arterial wall*, if the vessel has been tied in the usual way, is to divide the inner and middle coats, which are separated from the outer and curl up slightly, whilst the outer coat is constricted and thrown into folds within the grasp of the ligature. If an artery is tied in its continuity, the same effect is produced on each side of the ligature. The changes already described, by means of which the artery is obliterated and transformed into a fibro-cicatricial cord, manifest themselves in due order. If the ligature, however, is infected and irritating, it has to cut its way out

through the vessel wall by an ulcerative process akin to the separation of a slough, thus exposing the patient to the risk of secondary hæmorrhage.

Division of the inner and middle coats is not an essential element in *gaining satisfactory occlusion of a vessel, for it* can also be effectively accomplished by merely bringing the vessel walls into close approximation by means of a 'stay knot.'

In the place of ligature, simple **forcipressure,** which means that the divided end of the vessel is crushed between the strong and deeply serrated blades of a pair of forceps, of which the usual type is the Spencer Wells and the Kocher, may possibly suffice. On other occasions, **torsion,** which consists in twisting the vessel after seizure in a pair of forceps, may be employed. This procedure causes rupture of the inner and middle coats of the vessel just above the spot grasped so that they curl upwards into the lumen, whilst the outer coat is twisted distally to this point. A coagulum then forms upon the injured surfaces, and the subsequent progress towards permanent occlusion is the same as that which has been described in connection with the natural arrest of hæmorrhage.

C. **Other Accessories to Hæmostasis** are also available and have a limited application. They comprise the following measures:

(1) **Position.** When the bleeding is from one of the extremities, especially the lower, elevation by emptying the veins will determine a reflex contraction of the arteries, and thereby assist hæmostasis.

(2) **Cold** may be employed in the form of ice, cold water, or lotion, or simple exposure to the air, all clots, swabs, pledgets, etc., being removed for this purpose; it must, however, be remembered that ice and unsterilized water may convey infective germs. Such treatment is of most value for general oozing from vascular structures or into cavities such as the mouth, vagina, or rectum.

(3) **Hot Water** (130° to 160° F.) is a powerful hæmostatic. It is supposed to act by stimulating the involuntary muscular fibres of the vessel wall; but probably the coagulation of the albumen of the blood is an important factor, as unless the water is hot enough to blanch the surface of the wound the bleeding is not stayed but rather encouraged.

(4) **Cauterization** is but little employed as a hæmostatic, except for the bloodless removal of vascular tumours by one of the various forms of cautery. Occasionally, however, it is used for bleeding from tissues which are infiltrated and thickened by chronic inflammation so that a ligature cannot be applied, *e.g.* a bleeding vessel on the nasal septum. In order to seal effectually the mouths of the vessels, the cautery must be at a dull red or black heat; a bright red-hot iron cuts through a vessel as cleanly as a knife, and does not stop the hæmorrhage.

(5) **Chemical Agents** may be used to assist in checking hæmorrhage from spongy tissues or from deep cavities or organs. (*a*) They may act locally as *styptics* by causing direct coagulation of the blood, *e.g.* liq. ferri perchloridi or pernitratis, tannic or gallic acid, alum, nitrate of silver, styptic colloid, etc. In employing these the surface

of the wound must be cleaned and dried as far as possible, and the styptic then applied on lint or gauze. Unfortunately, the more active, such as liq. ferri perchloridi, are actively caustic, and may cause sloughing; it is seldom that such applications are necessary. (*b*) They may increase the coagulability of the blood, and of these lactate of calcium is the most effective. It is usually administered per rectum, in a small enema containing 15 grains, and this may be repeated two or three times a day. The use of this drug before operations which are expected to be very sanguinary has been most satisfactory in many cases. (*c*) They may be effective as *vaso-constrictors*, and of these the chief is adrenalin. It is probably more valuable in preventing than in checking hæmorrhage, and is largely used in intranasal work; it is prepared in the dry form, since it loses its power when kept in solution more than an hour or two. The addition of cocaine to its solution increases its activity. Its effect is, however, very temporary, and provision must be made to control reactionary bleeding when its influence ceases. (*d*) A large class of drugs of the astringent class are employed empirically under varying circumstances to assist in hæmostasis, *e.g.* turpentine, hamamelis, ergot, acetate of lead, etc.; but it cannot be said that their action, though appreciated, is fully understood. (*e*) Finally, it is most important in cases of internal hæmorrhage, as from the lungs or gastro-intestinal canal, to keep mind and body quiet, and there is no agent under these circumstances more valuable than *opium* and its salts.

Methods of Dealing with Hæmorrhage from Special Sources.

It has been stated that a temporary control of bleeding may often be effected by **digital pressure,** and this method should always be tried in the first place, particularly when the bleeding originates from any of the following sources; thus the common carotid artery may be controlled by grasping the neck from behind and compressing the artery by the fingers placed along the anterior border of the sterno-mastoid against the transverse process of the sixth cervical vertebra (Chassaignac's tubercle). Such pressure will also control the vertebral and inferior thyroid vessels. The *subclavian* is to be compressed in the third part of its course against the first rib by the finger or thumb placed immediately behind the clavicle, in the angle between it and the sterno-mastoid, the pressure being made downwards and inwards. A good deal of force is sometimes required in order to maintain the pressure, and this may be gained by superimposing the fingers or thumb of the other hand. When the pressure is to be kept up for some time, the padded handle of a door-key may be employed in the same way. The *facial* artery is compressed against the lower jaw just in front of the masseter muscle; the *temporal* artery, against the zygoma just in front of the ear; the *occipital*, at a spot about $1\frac{3}{4}$ inches from the occipital protuberance against the superior curved line. To control the *brachial* artery the arm should be grasped from behind, and the fingers pressed inwards along the inner margin of the biceps against the humerus. The *abdominal aorta* is controlled in slim individuals with ease by pressure through the abdominal

wall against the body of the third lumbar vertebra a little above and to the left of the umbilicus, *i.e.* just above its bifurcation; in stout persons this is impossible. The *common femoral* artery is best compressed immediately below Poupart's ligament. The surgeon should stand on the same side of the patient as the artery to be controlled, and use the finger-tips to press the vessel directly backwards against the pubic ramus. The fingers of one hand placed over the other are sometimes needed to maintain sufficient command. Hæmorrhage which is not controlled by digital pressure will require **operation,** and the following sites are some of the more common ones in which this method of treatment will be employed.

Secondary Branches of the Carotid.—If the divided ends of these vessels, either in the neck or head, *e.g.* in a cut throat or a punctured wound of the pterygoid region, cannot be secured, ligature of the external carotid between the superior thyroid and lingual should be undertaken rather than tying the common carotid, since the cerebral circulation is not thereby affected.

Vertebral Artery.—Hæmorrhage from this vessel is difficult to recognize, as it is impossible to compress it without also including the carotid; it is feasible, however, to control the carotid apart from the vertebral by pinching it up by the fingers placed on either side of the sterno-mastoid. Treatment must follow the usual course of securing the vessel at the bleeding spot, if possible, by ligature or hæmostatic forceps, which are left on for a time. In the upper part of its course the vessel may be exposed by clipping away a transverse process if necessary, due care being taken of the nerve roots. It is most essential that the carotid should not be tied by mistake in these cases, as thereby more blood is directed to the vertebral trunk, and the bleeding is correspondingly increased.

The Internal Mammary Artery rarely calls for treatment, since an accidental wound of this vessel is usually complicated with some graver mischief to heart, liver, or lungs. If recognized, tie at the bleeding spot, possibly removing a costal cartilage to gain access. The vessel lies about half an inch outside the border of the sternum.

Intercostal Hæmorrhage usually results from penetrating wounds also involving the rib, and is not easily stopped on account of the position of the vessels in the groove.

Treatment.—The overlying piece of rib should be removed so as to expose the bleeding vessel, which can then be isolated and ligatured. Failing this, and if a wound of sufficient size in the intercostal space is present, a piece of aseptic gauze like a pocket is pushed through into the pleural cavity, and packed tightly with wool or strips of gauze; on pulling upon this, firm compression of the vessel may follow with cessation of the bleeding.

Wounds of the **Palmar Arches** were formerly much more dreaded than they are at present, when effective asepsis and the use of the elastic tourniquet allow us to explore the depths of a wound without much danger or difficulty. The position of the wound will usually indicate whether the bleeding comes from the superficial or deep arch, but in case of doubt it is well to remember that pressure on the ulnar

trunk mainly affects the superficial arch, whilst pressure on the radial will chiefly influence the deep arch. A wound of the superficial arch presents little trouble in treatment, as it can readily be secured by catch forceps and ligature; but the deep arch is not so easily dealt with. It lies just over the bases of the metacarpal bones (Fig. 109, D), and to expose it the wound must be enlarged freely by a longitudinal incision, and the tendons turned on one side or separated. It may be possible to secure the vessel by forcipressure forceps, and these may be left on for twenty-four hours if a ligature cannot be applied. Of course, the strictest asepsis is needful in such cases, and passive movement of the fingers must be undertaken early, in order to prevent troublesome adhesions. Failing such means, or in infected cases, the wound is packed with sterilized gauze, and over this the fingers are firmly bandaged. The patient is kept in bed for a few days, and the arm elevated. Pressure on the main vessels above is scarcely necessary if the compress is accurately applied. The bandages may be relaxed at the end of twenty-four hours, but the deep dressing should, if possible, not be touched for three or four days. If, in spite of this, bleeding recurs, the main vessel or vessels of the limb must be tied. Ligature of the ulnar and radial arteries at the wrist is generally insufficient to control it, as there is often a communicating branch of some size passing from the anterior interosseous to the deep arch, and hence it may be needful to secure the brachial artery, ascertaining first, however, by pressure, that this will be efficacious, for occasionally there is a high division of the brachial, or a vas aberrans may exist, which would compel the surgeon to tie the third part of the axillary.

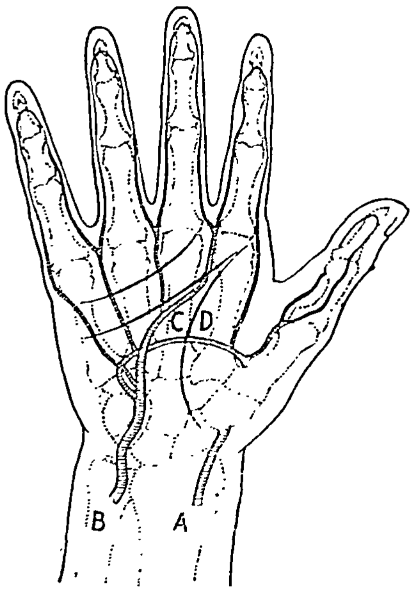


Fig. 109.—Hand, to show Position of Palmar Arches.

A, Radial artery; B, ulnar artery; C, superficial arch; D, deep arch.

Bleeding from the **Plantar Arch** must be conducted on similar lines.

The **Gluteal, Sciatic, or Pudic** arteries may be wounded by stabs in the buttock.

Treatment.—Enlarge the wound in the direction of the fibres of the gluteus maximus, *i.e.* downwards and outwards, and secure the bleeding vessel. The gluteal trunk emerges from the pelvis at the junction of the middle and inner thirds of a line from the posterior superior iliac spine to the great trochanter (Fig. 110), the pudic crosses the ischial spine at the junction of the middle and lower thirds of a line from the posterior superior iliac spine to the tuber ischii. The sciatic emerges from the pelvis just above and a little external to the latter spot. The pudic may also be divided in the perineum by a

penetrating wound. Failing ligature of any of these arteries at the seat of bleeding, the internal iliac should be secured.

General Treatment of Hæmorrhage.—When the loss of blood has been severe, the patient must be kept with the head low, whether syncope is present or not. The foot of the bed or couch should be raised, so as to assist in the maintenance of the circulation to the medullary centres. *Stimulants* may be necessary to maintain the heart's action, but *should never be given until the bleeding has been effectively controlled*, as, otherwise, they may increase or restart it. If death appears to be imminent, the arms and legs should be bandaged, or the abdominal aorta compressed, in order to confine the blood as much as possible to the head and trunk.

In milder cases of hæmorrhage all that is required is to restore the amount of fluid lost by the introduction into the circulation of a corresponding quantity irrespective of its quality, so long as it is harmless and can mix with the blood-plasma. **Infusion** of an isotonic salt solution is therefore capable of giving excellent results in suitable conditions. If the veins are or can be sufficiently distended, a metal needle is inserted into one subcutaneously, and through it two or three pints of the solution can be injected; but if, as is often the case, the veins are collapsed, an incision has then to be made over some suitable vein (*e.g.* the median basilic or cephalic, *just above* or below the flexure of the elbow, so that subsequently the scar shall not be troublesome), which is exposed and its distal end tied. A ligature is passed under the proximal end, and by exercising traction upon this the vein is temporarily kinked and loss of blood prevented. A longitudinal or oblique slit is then made in the vein, and the cannula, filled with the fluid so as to exclude all air, inserted; a half-knot tied around the cannula will prevent it from slipping. When the necessary amount of fluid has been introduced, the cannula is withdrawn, and the knot around the proximal end of the vessel completely tied. The amount injected varies with circumstances, but two or three pints are usually required; in case of need the process may be repeated, but rectal infusion will often suffice in the later stages.

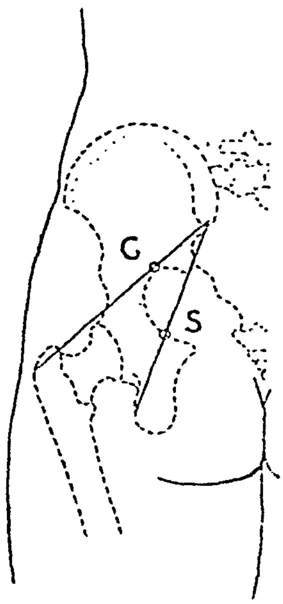


FIG. 110.—DIAGRAM OF PELVIS TO INDICATE SITES OF EMERGENCE OF G, THE GLUTEAL ARTERY, AND OF S, THE SCIATIC AND PUDIC ARTERIES.

As to the material, a warm saline solution is the best, consisting of a drachm of chloride of sodium to a pint of sterilized water to which 6 per cent. of gum acacia has been added. These solutions already sterilized are obtainable in bottles, and all that is required is to stand them in hot water until their temperature is raised to that of body heat. Of course, the apparatus is carefully sterilized, and no air must be admitted. The injection is made slowly, so that the solution

may be mixed gradually with the blood. It has been found by experiment that after an infusion following hæmorrhage the specific gravity of the blood is lowered for a very short period only, and rapidly rises to a normal level, or may even be raised above the normal. This suggests that the increased amount of fluid is absorbed into the tissues, and explains why it is sometimes necessary to repeat the injection more than once. Should the patient's hæmoglobin have dropped below 50 per cent., it is far preferable to give a continuous blood transfusion.

Fluid may also be introduced into the body through the rectum (*proctoclysis*), or through an exploring needle connected with a tube and funnel into the loose connective tissues of the buttock, abdomen, or submammary region (*hypodermoclysis*). In the latter case the funnel or receiver must be held at some height (five or six feet), in order to gain sufficient pressure, and by this means a pint or more may be slowly injected; a carefully sterilized syringe and a large needle may be employed for the same purpose. During the injection the part should be gently rubbed so as to distribute the fluid. Absorption is fairly rapid, but occasionally, in debilitated and septic subjects, sloughing and suppuration occur at the site of infusion, especially if the most careful precautions as to asepsis have not been taken. When hæmorrhage is associated with shock, the general treatment of the latter condition should be carried out at once.

Varieties of Hæmorrhage.

The source of hæmorrhage may be arterial, venous, or capillary, but it is more usual to refer to the bleeding as being Primary, Reactionary, or Secondary, according to whether it is delayed up to twenty-four hours or whether it occurs after that period.

Primary Hæmorrhage takes place as an immediate consequence of a wound and is mainly arterial in nature. It should be dealt with on the principles already enumerated in connection with the treatment of hæmorrhage in general. When the bleeding is venous in origin, it is usually of a less severe nature, and bleeding from the smaller veins rarely requires much attention, as the walls rapidly collapse after section.

In the case of larger veins, or in those in which collapse is prevented by surrounding fibrosis, as is the case with varicose veins, a very considerable amount of blood may be lost in a very short time. Divided veins should be ligatured in the same way as arteries, but it is often possible to secure a puncture or tear in a large vein by means of a lateral ligature without occluding its whole circumference. In the case of varicose veins, pressure with the finger will always suffice if the limb is raised in the air. A pad may then be applied over the opening.

Reactionary Hæmorrhage is usually arterial, and results from two chief causes: (*a*) Defective application of a ligature, which comes undone from being badly tied (a 'granny' knot), or slips off from including within its grasp other structures as well as the arterial

wall; or (*b*) the coagula lying in the mouths of divided and unsecured vessels are not sufficiently firm to withstand the increasing blood-pressure which supervenes after the shock has passed away, or which may be due to excitement or the injudicious administration of stimulants. This form is usually not very serious, inasmuch as it can only arise from the smaller vessels, all the larger ones having probably been recognized, and tied during the operation. Dense structures, such as scar tissue of the parenchyma of the mamma, are favourable sites for the development of reactionary bleeding.

Treatment.—Elevation and the pressure of a firm bandage are often quite sufficient to arrest this form of bleeding; but, if unsuccessful, the wound must be opened up, washed out with hot salt solution, and any bleeding vessels tied. The actual cautery may be employed to check oozing from the cicatricial surfaces, and if it is not allowed to touch the skin, and the wound kept aseptic, no delay in healing need be occasioned. Should the bleeding persist, the wound should be firmly packed.

Secondary Hæmorrhage.—Under this title are included all forms of hæmorrhage from wounds which occur after the lapse of twenty-four hours. It is almost always due to infection, and was formerly very common, often leading to a fatal termination; since the introduction of antiseptic surgery, it is but seldom seen, except where asepsis cannot be fully maintained, as in the mouth, pharynx, etc., or in the treatment of gunshot wounds.

The **Essential Cause** is **infection** of the wound. In a vessel which has been divided and ligatured, as on the face of an amputation stump, the projecting end of the vessel beyond the ligature is practically dead tissue, and, therefore, readily attacked by bacteria, which transform it into a slough, and this, together with the infected ligature, has to be cast off; when this happens, bleeding may occur. In addition to this, however, the infection of the wound involves a suppurative inflammation around the vessel (*periarteritis*), which results in a softening of the vascular tunics by the bacterial toxins, and this may progress in time to such an extent as to render them incapable of resisting the blood-pressure, so that, sooner or later, they give way. This latter condition is especially seen in vessels tied in their continuity, and also occurs in the secondary hæmorrhage which sometimes develops in connection with abscesses in the neighbourhood of large vessels, or in deep infected wounds where a drainage-tube, or other source of pressure, *e.g.* the spiculated end of a broken bone, is allowed to rest against an arterial wall.

Anything which interferes with the vitality of the vessel wall may serve as a **Contributory Cause**, such as its separation from the sheath for too great an extent, thereby cutting off its blood-supply; or a diseased condition of the arterial wall, as from atheroma, or an unhealthy condition of the patient's blood, or undue elevation of blood-pressure, as in Bright's disease.

After ligature of large vessels, such as the innominate, first part of the subclavian, or common iliac, secondary hæmorrhage may occur apart from infection, if the inner and middle coats have been divided

by the ligature. The crumpled-up outer coat exposed just above the ligature by the retraction of the inner and middle coats is insufficient to withstand the blood-pressure in such large vessels, and undergoes an aneurismal dilatation, which is certainly followed by hæmorrhage at an early date. Secondary hæmorrhage is nearly always arterial in nature, but may also be venous, and arises from infection around a vein which has been punctured or divided. Under aseptic conditions repair of the wounded venous wall is effected without cessation of the circulation in the main trunk. If the wound becomes infected, the ligature is invaded by germs, as also the portion of vein wall within its grasp. In the smaller veins the inflammation induced will result in a protective thrombosis; but in a large vessel, such as the internal jugular, where the blood-stream is rapid, thrombosis may be hindered in its occurrence, and hæmorrhage may result from the wall giving way. The bleeding from cases of this description will usually be severe, but can be easily controlled by pressure or ligature.

The **Phenomena** are almost always preceded by those of infection of the wound, to which a slight occasional loss of blood is added. This continues with more or less frequency and severity until the patient is either worn out by the constant repetition of small losses or destroyed by one or two severe gushes from the larger vessels. The earlier the bleeding occurs the less serious it is, as it probably comes from the smaller vessels, and can be easily dealt with. When, however, it does not supervene till later, as on the tenth or twelfth day, it usually arises from the larger trunks, and is increasingly severe. When originating from a vessel tied in its continuity, it generally comes from the distal end, since repair is here less effective than on the proximal side of the ligature, and resistance to bacterial infection less vigorous. The explanation of this is that the vasa vasorum reach the artery from the sheath, and the application of the ligature necessarily cuts off the blood-supply of the vessel wall just distal to the ligature.

Treatment.—The case must be watched night and day until the wound is healthy, as, although the bleeding ceases for a while, it may break out again at any time. If the wound is in a limb, a tourniquet should be lightly adjusted above it as a precautionary measure, so that at a moment's notice it may be tightened.

When arising *from an artery completely divided*, as in an amputation stump, elevation of the part after redressing and firm bandaging may be all that is needed in early cases. A recurrence will necessitate the opening up of the wound, and the application of ligatures to the bleeding vessels, if practicable. Sloughs should be cut or scraped away, and the wound packed with gauze soaked in flavine solution and firmly bandaged. If this fails, the artery must be tied just above, or re-amputation performed. When the bleeding comes from the main vessel near the trunk, as after amputation at the shoulder or hip, proximal ligature can alone be depended on, should local treatment be unsuccessful.

When coming *from an artery tied in its continuity*, the wound is

opened up, and the artery secured again above and below, whilst every effort is made to combat the infection. Failing this, proximal ligature may be practicable, but for the large vessels of the trunk pressure may be the only resource. Should religature at a higher spot fail or be considered inadvisable, as is often the case in the leg, amputation must be undertaken without delay.

In these cases blood transfusion is often of great value, because to the already debilitated patient the loss of blood may favour the spread of the ever-present infection.

The entrance of air into veins is, fortunately, a very rare occurrence, as it is always fraught with grave danger to the patient, inasmuch as it interferes seriously with the circulation, and may even cause death. The air sucked into the veins is carried to the right side of the heart, and there becomes entangled in the colomnæ carneæ, and is churned up into a frothy spumous mixture, which the heart can only eject with difficulty.

Hæmophilia.

Hæmophilia is an hereditary disease in males, characterized by deficiency in the thromboplastic substance of the blood which renders the individual liable to severe and repeated hæmorrhage. There is a tendency to persistent and uncontrollable bleeding from slight wounds, whether open or subcutaneous. This condition is often associated with extravasation of blood into the joints and certain consecutive phenomena (Chapter XXII.). The family history of the hereditary cases is interesting, the disease being usually transmitted through the females of one or more generations to the males, whilst the former may escape entirely. Unless hæmorrhage is actually occurring, nothing abnormal is noticed, but any injury is sure to be followed by excessive bleeding; spontaneous subcutaneous ecchymoses frequently occur, as also bleeding from the mucous membranes. Hence no operation must be undertaken on such patients unless absolutely urgent, even such a small matter as the extraction of a tooth having proved fatal.

When blood escapes from a damaged vessel into the tissues, or from a wound on a free surface, the extravasated blood gradually coagulates or clots, due to formation of a meshwork of fibrin. This clotting is a protective mechanism which safeguards the body against excessive loss of blood. The fibrin is formed by the action of thrombin on fibrinogen. Fibrinogen is a normal protein constituent of blood plasma, while thrombin is formed by the action of the thrombokinase on prothrombin in the presence of free calcium ions. When the blood escapes from the vessels it is acted upon by thrombokinase present in the tissue fluids, or formed from the damaged endothelium of the vessels, and also from the blood-platelets and leucocytes. With blood from normal persons, the time taken for shed blood to clot is practically constant under constant conditions. Using Dale and Laidlaw's method, in which the blood is allowed to flow into a capillary tube containing a lead shot, and maintained at 37° C., the time taken by the

blood to clot sufficiently firmly to arrest the lead shot is one and three-quarter minutes. This clotting time is prolonged in some cases of purpura, but the prolongation is especially marked in hæmophiliacs, and may be as long as thirty to forty minutes. The delay in hæmophilia appears to be due to a deficiency of thrombokinase, especially in the blood-platelets. The platelets are normal in numbers, but are defective in quality. The addition of normal platelets to hæmophilic blood causes normal clotting, and it has been shown that there is no deficiency either in the calcium or fibrinogen in the disease.

Treatment must be directed mainly towards the artificial provision of those substances which are defective in the blood. Whole blood transfusion is undoubtedly the best procedure, but there is now available a serum of hæmostatic value, known commercially as Hæmoplastin, which contains prothrombin and other bodies required for determining coagulation; 2 to 4 c.c. of this serum, diluted perhaps with normal saline solution, are injected under the skin, or for choice into a vein. Horse or ox serum given subcutaneously may also be of some use. Locally, pressure and cold are mainly relied on, but adrenalin, Hæmoplastin, or cocaine may be applied on gauze to the bleeding spot.

Snake venom (Russell viper) has of late been used in the treatment of this condition with encouraging results.

When hæmo-arthrosis is present, the joint should not be tapped on account of the danger of sepsis, but should be kept at rest.

Surgical Shock.

This term is applied to a condition resulting from trauma in which there is a marked depression or inhibition of the sensory and motor parts of the reflex arc, together with a marked fall of the blood-pressure, a lowering of the body temperature, and disturbance of the respiratory exchange. In this connection the term 'trauma' is used in its broadest sense to include operation, and such lesions as perforated peptic ulcer, strangulated hernia, etc., in addition to ordinary injuries.

Shock may be described as primary or secondary, according to its immediate or later relation in time to the causative lesion, although the former may pass readily into the latter. The condition known as local shock is a curious insensibility to pain on handling the injured part, which is sometimes found immediately after a severe injury, and appears to be a temporary sensory paralysis akin to 'concussion' of a nerve.

Primary Shock is the immediate outcome of the accident or lesion, and the fall of blood-pressure is in some measure beneficial, as it tends to limit hæmorrhage. The rapid onset of the symptoms suggests that the condition is due to reflex inhibition of the heart and vaso-dilatation, particularly of the splanchnic vessels, resulting in a marked fall of blood-pressure and sometimes loss of consciousness from cerebral anæmia. It is probably a reflex response to overwhelming efferent impulses and experimentally can be prevented by a preliminary cocainization of the nerves at a level proximal to the injury. A common

type of primary shock is to be seen in the collapse which follows a severe blow in the epigastrium.

Clinical observation has shown that the degree of primary shock depends on the nature of the injury and the number of sensory nerves involved. Thus, trauma to organs with a rich sensory supply, such as the testis, intestine, or hand, will produce much shock; an extensive laceration of the skin will be more productive of shock than a deep cut, and a superficial burn of first or second degree involving half the body surface is more dangerous than the complete incineration of a hand or foot. Similarly, records taken during operations show that at certain stages where sensory nerves are stimulated a well-marked

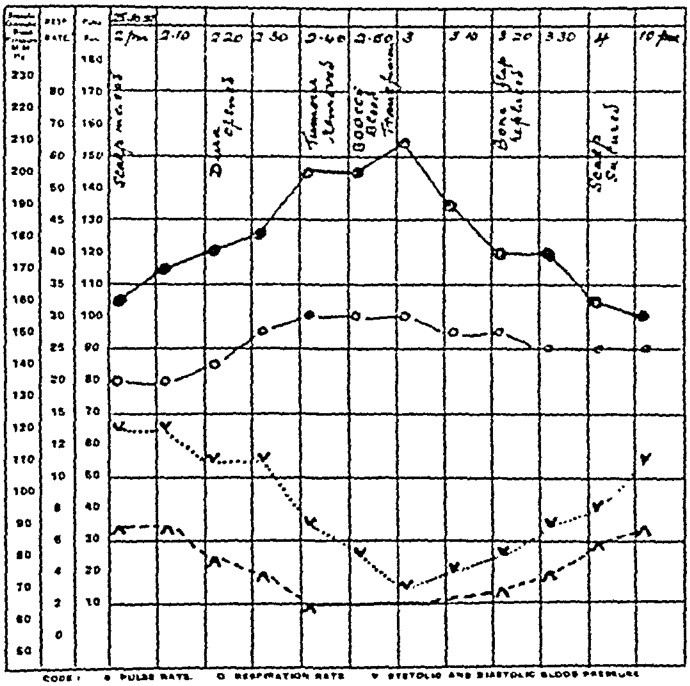


FIG. 111.—RECORD OF PULSE, RESPIRATION, AND BLOOD-PRESSURE DURING OPERATION FOR CEREBRAL TUMOUR, SHOWING DEVELOPMENT OF SHOCK WITH RECOVERY FOLLOWING BLOOD TRANSFUSION.

fall of blood-pressure occurs (Fig. 111), and this is intensified by rough handling or tearing of the tissues.

In addition to these factors the psychological attitude of the patient is important, for if the whole nervous system is in a state of tension in expectation of some painful stimulus, the general effect of that stimulus will be greatly increased; whereas if attention is diverted and an active interest aroused in other things, the immediate effect of the injury will be diminished. Thus it has been noted that, in the excitement of battle, soldiers have been severely wounded without realizing it or showing any evidence of shock at the time, whilst a trivial cut may produce profound collapse if the individual is fearfully anticipating the injury.

The **Symptoms** vary with the severity of the injury, from a slight

transient giddiness and faintness to complete prostration and even death. In a case of moderate severity the patient is relaxed and apathetic; the face is pallid and shrunken, and the forehead and upper lip are covered with a cold sweat. The pulse, at first slow and weak, soon becomes extremely rapid, often so feeble as to be imperceptible, and may be irregular; a sphygmomanometer shows a profound fall of systolic blood-pressure. Respiration is slow and shallow, and the temperature is usually subnormal.

After an interval, depending on the degree of shock and the treatment adopted, a stage of reaction occurs. The respirations increase in depth and frequency. The pulse becomes slower and fuller; the blood-pressure rises. Gradually colour returns to the face, and the body surface becomes warmer. The patient becomes less apathetic and muscular power returns.

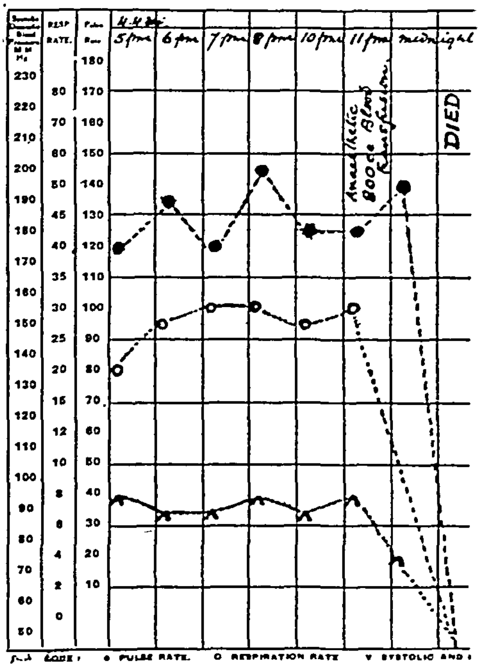


FIG. 112.—RECORD OF PULSE, RESPIRATION, AND BLOOD-PRESSURE IN CASE OF MULTIPLE INJURIES: PROFOUND SHOCK ENDING IN DEATH DESPITE TRANSFUSION.

Sometimes the stage of reaction is accompanied by irritability either of the mental or muscular system, leading on the one hand to traumatic delirium, and on the other to extreme restlessness, but it is probable that both these conditions are largely due to an associated toxæmia.

Secondary Shock or Collapse, as it is sometimes termed, arises some little time after the injury, either developing without a recognizable stage of primary shock, or following the stage of reaction described above; not unfrequently the patient passes from a state of primary shock into that of secondary shock without an interval of remission (Fig. 112). The condition is a common sequel to all severe injuries, and may be seen in the later stages of extensive operations, particularly those on the skull, thorax, or abdomen. It is always aggravated and its incidence favoured by factors which depress general resistance, such as exposure to cold, starvation, infection, and toxæmia; by conditions which lower the blood-pressure, such as hæmorrhage or weakness; and by anæsthetics which appear to sensitize the organisms to the action of histamine. Whilst primary shock shows a strong tendency to recovery with appropriate treatment, secondary shock establishes a vicious circle difficult to break. The exact nature of this delayed shock is still under discussion, although various factors have been elucidated.

All observers are agreed that the constant feature is the depression of the blood-pressure from the normal systolic pressure of 110 to 120 mm. of Hg to 50 mm. or below. In the anæsthetized animal, with trauma applied to the muscular part of the thigh, the common finding is an initial fall of blood-pressure (stage of primary shock), followed by a rise (stage of reaction), and then from one to six hours later a profound fall to shock level.

A marked reduction of the blood-volume is also recognized as a prominent feature of the condition. This was originally thought to be due to a peripheral vaso-constriction, with consequent engorgement of the splanchnic and visceral vessels, but the pallor and bloodlessness of the viscera found at operation or post-mortem shows this view to be incorrect. Moreover, various observers have noted an increased red cell count in the capillary blood as compared with that of the veins, together with an increased hæmoglobin content of the blood even up to 125 per cent. This indicates that loss of the plasma is an important factor in the diminution of the blood-volume, and the consequent increased viscosity of the blood still further slows the peripheral circulation. As a result of this, oxygenation of the tissues is diminished, and there is an accumulation of incompletely oxidized products of metabolism leading to a condition of acidosis.

On the experimental side the field has long been dominated by the work of Bayliss, Cannon, and others during the later years of the war. Their experiments appeared to show that secondary shock resulted from the production, in the injured tissues, of a toxic substance which entered the circulation and caused the general phenomena of shock. The isolation of histamine from muscle tissue and the demonstration that histamine on injection produced a profound fall of blood-pressure was a further step; and although the post-mortem appearances of 'histamine shock' differ from those of traumatic shock, it seemed reasonable to assume that some similar product of injured muscle was responsible for the development of delayed shock.

Recently this work has been severely criticized. Blalock and others have shown that the extravasation and exudation into the injured part was not fully measured in the earlier experiments. When this local extravasation is accurately measured it is found to amount to between 40 and 50 per cent. of the total blood-volume, and they have shown that bleeding an animal to this extent will produce shock in the absence of trauma. In addition, Blalock has shown that the transfusion of blood from a shocked animal into an uninjured animal does not produce shock in the recipient, thereby proving that there is no vaso-depressor substance circulating in the donor's blood. This result has been confirmed clinically by Schneider, who failed to produce a fall of blood-pressure, either in men or animals, by the injection of blood from shocked patients.

Recently O'Shaughnessy and Slome have brought forward further experimental evidence.* They confirm the failure to demonstrate a vaso-depressor substance in the blood, and they agree that in severe trauma the reduction of blood-volume by local extravasation will

* *British Journal of Surgery*, xxii., No. 87, p. 589.

account for the shock. In less severe injuries they find the local fluid loss is itself insufficient to produce shock, and they have shown that shock will only develop if the nerves from the injured limb are intact. Section of all nerves from the limb prevents the onset of shock; with the thigh as the site of trauma, spinal anæsthesia delays the fall of blood-pressure until the limb reflexes return. Moreover, in an already shocked animal, spinal anæsthesia causes a marked recovery of the blood-pressure, which persists until the effect of the anæsthetic wears off.

The conclusion thus reached is that the factors responsible for shock are the local fluid loss by extravasation, and vasomotor depression by reflexes from the site of injury. The various workers are, however, careful to emphasize the fact that their conclusions apply only to traumatic shock, and that toxæmia may play a part in other types of shock.

The **Symptoms** of secondary shock correspond practically to those of the later stages of primary shock. The patient lies in bed in a condition of apathetic torpor, from which he is aroused with difficulty, when he will answer intelligently but faintly. The surface of the body is cold and pallid, often covered with a cold clammy sweat; the lips and the extremities of the nose, ears and fingers gradually become blue and livid; the eyes are sunken, the mouth is parched, and the patient complains of intense thirst. The temperature is subnormal and falls gradually; the pulse is weak and running, and may be uncountably quick; the systolic blood-pressure is 40 to 50 mm. Hg or lower; respirations are rapid and shallow, and become irregular. Gradually the patient passes into a state of complete unconsciousness, urinary and fæcal incontinence may ensue, and death occurs with respiratory failure. At post-mortem examination nothing peculiar is found except a general bloodlessness of all organs.

Diagnosis.—1. From the general results of **hæmorrhage.** Restlessness and thirst are then prominent signs, and the mental condition is less affected. However, some degree of shock is often present, and in severe cases of shock the diagnosis may depend on careful examination to exclude internal or external hæmorrhage. An estimation of the colour index of the blood may help, since it is normal in pure shock, but is lowered following hæmorrhage.

2. **In concussion of the brain** shock is also present to some extent, but there is an additional evidence of injury to the head, with unconsciousness, followed by vomiting as recovery occurs. After recovery the patient has no recollection of events which occurred immediately preceding the accident.

3. The onset of vomiting under an anæsthetic may simulate shock, but is easily distinguished by the progress of the case.

Treatment.—In slight cases of primary shock very little is needed beyond resting quietly for a few minutes, and the use of some stimulant such as sal volatile or brandy. In moderate cases the patient is also wrapped up and kept warm and some warm drink administered. In more severe cases he is laid recumbent, with head low, and every care is taken to avoid loss of body heat during the necessary examination to determine the nature of the lesion.

The question of immediate operation, assuming facilities to be avail-

able, calls for careful judgment. In certain cases, *e.g.* internal hæmorrhage, operation is a life-saving measure and should be undertaken without delay. In others, the risk of extension of the lesion, and of greater liability to secondary shock if operation is delayed, must carefully be weighed against the risk of operation during the stage of primary shock. Thus, in cases such as perforated peptic ulcer, it is almost imperative to delay operation for an hour or so to give the patient a chance of resuscitation with appropriate treatment. In other instances, where local or regional anæsthesia is possible, the blocking of nervous impulses from the lesion hastens the patient's recovery from primary shock, and immediate operation would be justifiable.

When immediate operation is inadvisable, temporary measures must be taken to deal with the lesion; hæmorrhage should be checked, and the injured region immobilized as far as possible. The patient is then put to bed with the head low, the end of the bed should be raised, and he is disturbed as little as possible. The body temperature is raised by the use of warm blankets, suitably protected hot-water bottles, or by placing under the bedclothes, supported on a cradle, one or more electric lamps of sufficient strength to raise the temperature of the air round the body to between 100 and 105° F. In the United States the oxygen tent is much in use for the treatment of severe shock and has proved of value. Pain is relieved by the use of morphia in full doses, according to the age and condition of the patient. If he is conscious, warm drinks are given; if unconscious, fluid should be given per rectum, as glucose saline (2½ to 5 per cent. glucose in isotonic saline), or as hot coffee, which has a certain stimulating effect. In severe cases it is advisable to give 1 or 2 pints of isotonic saline intravenously; the saline should be at a temperature of 104° F., and not more than an ounce should be given per minute.

In all cases of **operation** during or immediately after shock, or where shock may be expected to develop, every care must be taken to protect the patient from the contributory factors indicated above.

(i.) He should not be unduly purged or starved beforehand, and the taking of fluids by mouth should be permitted until two or three hours before operation. Where acidosis exists, alkaline drinks or an infusion of alkaline fluid should be given. The incidence of shock may often be prevented by commencing intravenous infusion of saline or blood transfusion before operation, and continuing it slowly throughout.

(ii.) In nervous patients the pre-operative injection of morphia (gr. $\frac{1}{6}$ or $\frac{1}{4}$) or of omnopon (gr. $\frac{1}{3}$ or $\frac{2}{3}$) is desirable, but should be combined with atropine to offset the possibility of depressant medullary effects.

(iii.) The bodily heat must be conserved by suitable clothing and the avoidance of undue exposure, while the temperature of the operating room should not be below 70° F.

(iv.) When practicable blocking of nerves by local, regional, or spinal anæsthesia is desirable, and if a general anæsthetic is required chloroform must be avoided. Ether has some slight toxicity, but is prob-

ably more effective than gas and oxygen for blocking nervous impulses, and, in addition, possesses valuable stimulating properties.

(v.) In the course of operation rapidity of execution should be aimed at, but gentle handling and exactitude must not be sacrificed to speed.

While attention to these points may prevent the onset of secondary shock, once the condition is established treatment becomes more difficult. In view of the recent experimental work, the primary consideration should be to minimize further exudation at the site of injury, and to diminish the nervous impulses arising from the part. Thus the success of the tannic acid treatment of burns is largely due to the coagulum preventing further exudation and diminishing the painful stimuli. Similarly it should be remembered that efficient immobilization of an injured part is a most important factor in preventing further exudation and in diminishing the local nervous impulses, not only in the case of fractures, but also in injuries of the soft parts. The use of local or regional anæsthesia will, as already mentioned, completely block the nervous impulses, and is of the greatest value where an operation has to be performed on a shocked patient; recently it has been put forward as a possible line of treatment for shock, although the patient may relapse as the anæsthesia wears off.

After attending to the primary lesion, the question of restoring the blood-volume arises. The intravenous infusion of isotonic saline has long been used for this purpose, but its effect is transient, as a pint of saline is lost from the blood into the tissues within thirty minutes of its administration. If given by a 'continuous drip' method (3 to 5 pints in twenty-four hours), the effect on the blood-pressure is less marked but more prolonged, and the method is of value in severe cases of shock. Bayliss advises the use of a 6 per cent. solution of gum arabic in normal saline, since the colloidal gum remains within the blood-vessels and exerts an osmotic pressure, which attracts fluid from the tissue spaces, thus increasing the blood-volume further. A pint of this solution (sterilized and filtered) should be given slowly, and in favourable cases will produce a rise of blood-pressure which persists. Recently the use of hypertonic saline has been described: 40 c.c. of a 30 per cent. solution are given intravenously and produce an immediate rise of systolic pressure, often to above normal, followed by a fall, but this is not marked, and the blood-pressure is usually maintained above 'shock level.' This solution acts by osmotic attraction of fluid from the tissue spaces, thus increasing the blood-volume, but it is particularly indicated in conditions of shock associated with a deficiency of the blood chlorides, *e.g.* intestinal obstruction.

The actual transfusion of blood is often useful (*vide* Fig. 111), but may be disappointing in its effect (Fig. 112). It is most valuable in cases of shock associated with severe hæmorrhage where the patient's condition is aggravated by anoxæmia from the lowered hæmoglobin. In pure shock the loss of blood-volume is a loss of the fluid portion of the blood, and transfusion in these cases is of less value than the use of intravenous saline. The hæmoglobin content of the blood may

be taken as a guide; in shock a fall of hæmoglobin below 70 per cent. would form an indication for a blood transfusion.

Attempts to raise the blood-pressure by stimulants should be made, but are often of small avail; coramine, icoral, and pituitrin are the most useful and should be employed in full dosage. Adrenalin and ephedrin may also be tried, but are usually of little practical value. Hot, black coffee per rectum is sometimes a valuable help.

General treatment regarding posture and the maintenance of body temperature should be carried out as described for primary shock.

CHAPTER X.

THE GENERAL TECHNIQUE OF OPERATIVE SURGERY.

No one who has been brought up in the modern school of antiseptic or aseptic surgery can have any idea of the horrors that were perpetrated under the name of surgery by our ancestors. Anæsthesia was unknown, and perhaps this was an advantage rather than otherwise, as it limited the number and the scope of operations. Patients had to be forcibly restrained during the procedure; hæmostatic forceps were not in existence, and the operating theatre was not the quietly decorous spot that it now is, but rather resembled the shambles. The wards were a hotbed of surgical fever, and erysipelas, pyæmia, and other manifestations of pyogenic infection led to an appalling post-operative death-rate. Hospital gangrene, wound phagedena, and other affections now happily extinct, were common enough, and not unfrequently wards had to be entirely closed in order to limit the ravages of such diseases. The almost synchronous discovery of anæsthesia and antisepsis has transformed surgery, and from being an art dangerous, barbarous, and almost repulsive, it has been changed into a scientific procedure, beautiful in its details and beneficial in its results.

The **Antiseptic** plan of treating wounds, as originally introduced by Lord Lister, is an outcome of the germ theory of putrefaction. It has for its object the prevention of bacterial development in wounds by the use of *chemical agents*, some of which are true germicides, capable of destroying the bacteria, whilst others merely prevent or inhibit their growth.

Biniodide of Mercury is a potent antiseptic, which has been chiefly employed in the form of a 1 in 500 solution in 70 per cent. methylated spirit for the purification of the hands or of the skin of the patient. It is, of course, extremely toxic. A 1 in 2,000 aqueous solution is also employed for the hands, and is less harmful to instruments than the perchloride.

Boric Acid is a mild and weak antiseptic, which may be utilized when stronger remedies might prove harmful, *e.g.* in plastic operations and for infants. It is also useful when antiseptic fomentations are required in treating inflammatory phenomena, and in ophthalmic surgery.

Iodine is a most valuable antiseptic, and at the present time is largely employed to sterilize the skin before operations in alcoholic solutions, varying from 2 to 5 per cent. To be effective, it is essential that the skin surface be previously freed from grease, and therefore in emergency cases it should be washed over with ether or acetone.

Iodoform is a yellow powder of characteristic and unpleasant odour, which probably acts by being decomposed in the tissues and slowly giving off iodine. Commercial iodoform is usually contaminated with a variety of germs; it is therefore wise to wash the iodoform before use in 1 in 20 carbolic lotion. Its chief value is in foul or tuberculous wounds, and, indeed, it seems to have a specific inhibitory action upon the development of the *B. tuberculosis.*

Lysol (or one of the many substitutes for it) is another useful antiseptic derivative of coal-tar. It is freely soluble in water, and as a 2 per cent. solution may be used in syringing out cavities, such as the vagina, external ear, etc. Its solution is somewhat soapy, and tends to cling to the tissues and prolong its action.

Dettol is a useful general antiseptic. It is a halogen derivative of xylenol dissolved in a mixture of aromatic essential oils. The oils are dissolved in a neutral solution of a suitable soap to render them miscible with water, thus forming a permanent emulsion when diluted. Dettol is a clear, light yellow fluid. It is miscible with water in all proportions, forming a fine emulsion. It can be used for sterilization of the skin, for sterilization of instruments, or for lotions.

Permanganate of Potash, Sanitas, and **Peroxide of Hydrogen,** all act in the same way as oxidizing agents; they are necessarily unstable, and cannot be utilized for dressings, and are therefore chiefly employed in the disinfection of cavities or wounds already contaminated. The most potent of these is peroxide of hydrogen, which is sold as a fluid capable of setting free 10 to 20 times its volume of nascent oxygen. It is quite unirritating, and may be poured directly into an infected wound, or even into the peritoneal cavity; forthwith it commences to effervesce, liberating its oxygen, and forming a frothy foam, which is likely to bring to the surface any loose sloughs or foreign bodies. Hydrogen peroxide is therefore particularly useful for washing out wounds which are liable to be infected with anaërobic organisms, *i.e. B. welchii* or *B. tetani.*

Hypochlorous acid and the **hypochlorites** have been much employed recently in the treatment of infected wounds, and undoubtedly have great antiseptic power *in vitro.* They are derived from bleaching powder or chloride of lime, and the chief forms in which they are used are as follows:

Eusol is prepared by the action of boric acid on bleaching powder in the presence of water, and contains about 5 per cent. of hypochlorous acid. If kept cool and in the dark, it retains its antiseptic power for three or four weeks, but rapidly loses it in contact with living tissues or on warming, and hence must be used cold. It may be employed as a lotion to irrigate wounds, or may be applied directly on gauze as a compress, or even as a substitute for Dakin's solution in the Carrel treatment. It is, however, strongly alkaline, and when once the wound is clean, its prolonged application is harmful and hinders healing.

Dakin's solution (or rather Daufresne's modification thereof) is free from caustic alkali, and contains from 0·45 to 0·50 per cent. of hypochlorite of soda; if a smaller percentage of hypochlorite is present, the

solution is inefficient; if more than 0·50 per cent. is present, it is irritating. The preparation requires much care, and inasmuch as bleaching powder is not of a uniform strength, its chlorine content varying from 20 to 37 per cent., it ought always to be tested first, and the amount of carbonate and bicarbonate of soda is regulated by this, the higher percentage of chlorine requiring more alkali; the finished product is again tested to ensure its accord with the standard indicated above.

Chloramine-T is a stable hypochlorite compound which retains all the advantages of the above solutions. It is readily soluble in water at ordinary temperatures, and a 2 per cent. solution is generally advised for wounds. It may also be employed in the form of an ointment (10 per cent.), or to infiltrate gauze (5 per cent.). As a lotion it may be applied not only for irrigation purposes, but also to wet gauze for packing wounds, and for washing out mouth, nose, throat, or vagina.

The **Aseptic Method** of treating wounds consists in the elimination of chemical antiseptics as far as possible, and the substitution of heat, dry or moist, as a sterilizing agent. Every efficient antiseptic is more or less toxic and irritating, and there can be no question that from an ideal standpoint the less they are introduced into wounds the better. No more satisfactory germicide can be imagined than heat, in the form either of boiling water or of steam under pressure, and if everything brought in contact with the wound is aseptic, then no antiseptics need be employed. Dressings, swabs, towels, aprons or coats, and caps are sterilized in drums or kettles by means of steam at ordinary pressure, or by superheated steam at high pressure. The latter, of course, is the more satisfactory, owing to its greater penetrative power, but the former can be effective if the drums are so constructed as to permit a free passage of steam through the articles to be sterilized, and if the latter are packed loosely and not tightly. The drum is first lined with a layer of lint or gauze, and a similar covering must be placed over the contents beneath the lid. A sliding shutter, or some suitable contrivance, allows the entrance of steam into the drum. When the drum is removed from the sterilizer, this shutter is closed, and the contents may be expected to remain sterile for a day or two, but not for long unless hermetically sealed.

For large hospitals an extensive and expensive sterilizing plant has to be installed, and probably some variety of the Washington-Lyon sterilizer is the best. Gowns, caps, and towels are usually dealt with in drums, but dressings and swabs are treated separately in packets wrapped in two layers of towelling, and for ward dressings two or three towels are added to these. The absence of antiseptics lays a heavy responsibility on those whose duty it is to prepare these materials, and all practicable foolproof checks should be utilized to avoid mistakes. Sterilizers, like all other machines, can get out of order, and it is quite possible for the process to be conducted without any steam reaching the contents. A 10-inch vacuum should first be produced to extract all air from the dressings. Steam is then admitted at 15 pounds pressure per square inch and allowed to circulate for twenty minutes. A 15-foot vacuum then follows to extract all the steam and so dry

the dressings. The danger of unsterilized packets getting mixed with the sterilized must also be provided for, as also of sterilized packets becoming subsequently contaminated. A recording steam gauge should always be connected with the inner chamber of the sterilizer, and each packet of dressing should contain a slip of paper with the date of preparation written thereon in an ink which changes colour only when effectively exposed to heat. An indelible silver ink which writes red, and is turned black on exposure to heat, and runs in the paper with moisture, is suitable for this purpose, and can be obtained.

For small establishments a Schimmelbusch's low-pressure dressing sterilizer or a small high-pressure (5 to 15 pounds) steam sterilizer answers excellently. For private practice supplies of effectively sterilized articles in hermetically sealed tins or drums can now be obtained from many instrument makers and chemists.

The **actual details of operative technique** vary somewhat with different surgeons, but the main principles which govern modern operative surgery are much the same in all, and the following sketch of the preparations required and of the routine usually practised in undertaking an operation may be considered more or less typical of modern methods:

1. **The Operating Room.**—The arrangement of this necessarily depends upon considerations of space and finance. It should not be unnecessarily large, and the old-fashioned 'theatre' with tiers of seats overlooking the central area is not desirable. Onlookers should have a low gallery provided for them, but little raised above the floor-space and shut off from it not merely by a rail, but by a glass barrier half-way to the ceiling. It may with advantage be placed between the operating area and the source of light, but clear of the window, or to one side, and should be entered by a separate passage. A north light is desirable, and it should come, not from the top, but from the side, in the form of what is known as a 'studio light.' The walls should be free from ledges on which dust may accumulate, and lined with white tiles or glazed bricks, or, better still, present a smooth enamelled surface, which can be washed down with a hose; of course, all corners should be rounded. The floor must be impermeable, and slope towards an open channel on one side of the room, so as to allow of suitable flushing with a hose. All shelves must be made of glass, but the fewer fixtures the better. The heating arrangements should be such that the temperature can be raised, if necessary, to 75° or 80° F. A suitable series of smaller rooms should be available for the surgeon and anæsthetist, for sterilizing purposes, etc. Artificial light must be provided, and electricity should always be employed for the purpose. Gas must be excluded as an illuminant, firstly from the risks of igniting ether vapour, and secondly from the chemical changes induced thereby in chloroform, resulting in the production of poisonous fumes. The lamps should, for choice, be fixed to the extremity of a long arm attached to one of the walls, thereby avoiding the presence of dust-collecting wires and pulleys over the table.

In a private house the room must, if possible, be carefully prepared beforehand. The carpet should be taken up and curtains removed. The walls should be wiped over with an antiseptic solution, and the floor

thoroughly scrubbed; all unnecessary furniture is removed. Should the operation be an emergency one, without time for such complete preparation, it is often wiser to leave things alone, and not stir up dust and dirt by a hurried attempt to make the place look a little better than it really is. A suitable supply of hot and cold boiled water must be secured beforehand, and basins and dishes, etc., should, if possible, be previously boiled.

2. The **Surgeon** must remember the very grave responsibility that rests upon him in undertaking any of the modern operations, and he must be willing and ready to submit himself to the strictest régime. In a general hospital he will lay aside all his clothes and boots, and don an operating suit consisting of a soft white shirt, white 'drill' trousers, and a pair of clean shoes; he will then proceed to purify his hands and arms, and finally puts on a sterilized gown reaching to the wrists, a sterilized cap and mask covering the whole face except the eyes, and sterilized gloves reaching *over* the lower end of the sleeves. The *assistants* will be similarly prepared. Where such a complete change is impossible, the shirt-sleeves must be turned up well above the elbows, and other preparations made as before. During the operation unnecessary talking is forbidden, and if one has to cough or sneeze the head is turned completely aside.

Similar rules hold good in regard to the *nurses*, who should wear sterilized gowns, and caps to cover the hair. Those actually assisting in the operation will also wear masks and gloves, and all others present wear gowns, caps and masks. In all operations involving the upper part of the body the *anæsthetist* must also be suitably garbed, and his hands and apparatus sterilized or protected.

The **hands** and **arms** must be as thoroughly and effectively purified as if no aseptic coverings were available. They are scrubbed thoroughly with soft or ether soap and hot water; the nails are cut close, special attention being directed to the semilunar folds of skin at the base, where infected material is apt to collect. For this purpose a purified nail-brush is employed with advantage, and if a running stream of hot water can be obtained, so much the better. It is possible that simple washing with soap and hot water for ten minutes is sufficient to purify the hands and arms.

The thin **rubber gloves** used in general work can be sterilized by dry heat, or boiled in water without soda. Dry sterilization is preferable, but unless care is taken the gloves are liable to be damaged. The interior is well dusted with talc powder, and a piece of gauze introduced to keep the surfaces apart; the ends should be folded up over a piece of gauze so that the glove can be put on without touching the outer surface; the gloves are finally placed in a cotton bag for sterilization. To put on such gloves, the hands after effective washing and purification are dried on a sterilized towel, and dusted over with sterilized talc. The glove is held by the turned-back cuff and slipped on so that the bare hand never touches the outer surface; this point is of particular importance. If gloves are boiled, they must be partly filled with water and placed in a bag or cage; otherwise they float to the surface and do not get completely sterilized. Boiled gloves are

best put on by everting them, and anointing the interior with sterilized glycerine; or the hand may be immersed in methylated spirit, and the glove then slips on easily.

3. **Instruments** are sterilized by boiling in a weak solution of bicarbonate of soda (1 per cent.) for ten minutes, or more if they have been previously used for a dirty case. To prevent them from rusting they should be carefully plated, and the water ought to boil for some minutes before they are immersed, in order that the suspended air may be driven off. After boiling they may be laid out on a sterilized dry towel and covered over with a similar towel till they are required, or kept in a weak antiseptic solution, *e.g.* carbolic lotion, 1 in 60. Mercurial solutions should be avoided, as they spoil the instruments. If during an operation an instrument which has not been previously sterilized is required, it may be quickly purified by immersing it for half a minute in liquefied carbolic acid, the excess of which is removed by washing thoroughly in alcohol or hot sterilized water. The same process or re-boiling must be adopted for any instrument which falls on the floor or becomes otherwise soiled. Special care must be directed towards the forceps, to see that the serrations are freed from dried blood-clot and other dirt. Hæmostatic forceps should be opened before boiling.

4. **Swabs** have now so completely taken the place of sponges in surgery that it is unnecessary to consider the preparation of the latter. Swabs are made of absorbent wool wrapped in a single square layer of gauze, the corners of which are tied across and tucked in; or they may be composed of gauze alone, folded over, and perhaps stitched so as to leave no free edge which may fray out; or they may be formed of larger squares of absorbent material, such as gamgee tissue. A sufficiency of these, suited in size and shape to the requirements of the case, is provided before the operation. They are sterilized in a suitable autoclave or sterilizer, and kept in the drum until required, when they are removed by sterile hands or instruments to a sterile receptacle, being used dry or after immersion in lotion. In case of need, where a sterilizer is not available, they may be boiled and then kept either in boiled water, covered over till required with a sterilized cloth, or in an antiseptic solution; or may be dried in an oven after being enclosed in a suitable cloth.

Cloth and gauze strips for abdominal operations are prepared in a similar manner. In these cases a careful record must be kept of the numbers used, so that all may be accounted for afterwards; indeed, it is wise always to have swabs, etc., done up in packets or bags containing a known number, such as a dozen. Furthermore, any swab inserted into the peritoneal cavity should always have a pair of artery forceps attached to a piece of tape at one corner of the swab. Strict adherence to this rule will often prevent the calamity of a lost swab in the abdomen.

5. The **Ligatures** and **Sutures** demand very thorough purification, which varies with the material used. Silkworm gut, horsehair, and silver wire, which do not imbibe fluids or become absorbed, merely require to be boiled, but silk and catgut need much more care if stitch

suppuration is to be avoided. **Silk** must be boiled for thirty minutes, and should be wound loosely on reels or winders, so that the deeper strands may become sterile as well as the superficial. It may be used at once after being kept in spirit or in some antiseptic lotion, such as a solution of sublimate (1 in 1,000), for a week or until required, so that its strands may become well impregnated with the salt. Silk should also be sterilized by steam previously to the boiling, as it is doubtful whether spores are always killed by prolonged boiling.

Catgut is still more difficult to purify, inasmuch as boiling in water is out of the question. Lord Lister claimed that catgut, prepared according to his directions (p. 315), remains actively antiseptic for an indefinite period, and that it suffices before use to immerse it in a 1 in 20 solution of carbolic acid for a quarter of an hour. The majority of surgeons, however, prefer to sterilize it before use, and especially so if they use non-chromicized gut or catgut which has been hardened in a 5 per cent. solution of formalin for twenty-four hours. Many different processes have been recommended, but perhaps the simplest and most effective is that known as the ' iodine ' method. The catgut is wound loosely on a glass spool or winder, and immersed in a solution containing iodine, 1 part; iodide of potassium, 1·75 parts; and distilled water, 100 parts. It is kept thus in the dark for twelve days, and then removed and kept dry, wrapped in sterile gauze or placed in sealed sterile bottles. Before use it is placed for a few minutes in alcohol (rectified or methylated), so as to dissolve out a little of the excess of iodine present. Catgut so prepared is not only aseptic, but also actively antiseptic, and rarely causes trouble in the tissues (except, perhaps, in delicate children). An extensive experience of this material for some years has proved its reliability and value. Various instrument-makers provide sterilized catgut in sealed glass tubes, which can usually be trusted.

6. The **preparation of the patient** must be directed not only to the site of operation, but also to the general condition. If the operation be one of any gravity, it is often wise to let the preceding day be spent quietly and restfully, possibly in bed. An effective evacuation of the bowels should be secured, but undue purgation is quite unnecessary; only a light evening meal is permitted. A good night's sleep is essential, and if need be a hypnotic is administered; this is the more important if by any chance the operation is put off, and for want of it mishaps, such as attempted suicide, have occurred. An operation is to many a terrifying procedure, and the *morale* of the patient must be studied, and undue fear countered by cheery conversation and company. Nurses by chattering about previous cases and experiences may do an infinity of harm. On the morning of the operation an enema is usually desirable, and some simple fluid nourishment is administered two or three hours previously.

The *skin* of the patient must be cleansed beforehand, in accordance with the instructions of the surgeon. Many methods are available and effective, but the following, which has been tested abundantly, is perhaps the best and simplest: The part is shaved, possibly the preceding evening, and washed with ether soap and hot water. It is

then thoroughly dried with a sterile towel, and if thought necessary swabbed over with ether or acetone. A 2 per cent. solution of iodine in 95 per cent. alcohol is then painted over it and allowed to dry, and a sterile dressing applied. This painting with iodine is repeated once again at the time of operation.

Picric acid (1 per cent. in water or 3 per cent. in spirit) may be employed instead of iodine. It is more penetrating, and therefore more effective and persistent; it is much cheaper, as methylated spirit may be used with it; but it is liable to stain the dressings and bedding, etc., and is therefore disliked by nurses. After the preliminary washing with soap and water a piece of sterilized lint soaked in the aqueous solution is applied, and over this non-absorbent wool (sterilized) is bandaged. At the time of operation the 3 per cent. spirituous solution is painted over the part.

Harrington's solution is used by some surgeons in the final preparation of the skin; the area is swabbed over with it, and after a few moments it is washed off with methylated spirit. The formula is as follows:

Methylated spirit 94 per cent.	640 c.c.
Acid. hydrochlor. (commercial strong)	60 c.c.
Hydrarg. perchlor.	0·8 grm.
Water	300 c.c.

Special care must, of course, be given to all parts where dirt is liable to accumulate, such as the umbilicus, external ear, toes, or corona glandis in a person with a long prepuce; but undue scrubbing and rubbing are to be deprecated as likely to determine a certain amount of dermatitis, or to wake up into activity germs lying dormant in the deeper part of the skin.

7. The **area of operation** is surrounded by sheets, which should always be sterilized, and these in turn are covered with dry sterilized towels, fixed to the skin by suitable towel-clips. Failing dry sterilization, the towels may be boiled and subsequently dried by baking in an oven, or soaked in an antiseptic solution. As soon as the incision has been made, sterilized cloths or towels made of 'tetra' or other similar material may be clipped over the edges of the skin so as to prevent the surgeon's hands from being in contact with it and thereby causing defilement.

8. The **operation itself** should be carefully thought out in advance and carried through without undue delay. The mere exposure of the subcutaneous tissues to the air does some amount of harm and necessarily increases the risks of infection. The absence of pain granted by anæsthesia is no justification for dawdling, but nothing is gained by undue and showy rapidity. Gentle handling of the tissues and the absence of unnecessary force are essential elements of good operating that must never be overlooked. Clean cutting does less harm than tearing tissues apart, which always means increased reaction. Bleeding should be reduced to a minimum, and known vessels may be picked up with advantage by hæmostatic forceps before division, especially in the axilla and neck.

9. Before closing the wound absolute **hæmostasis** should be secured, and then the wound may usually be stitched up completely and without drainage. It is important to build up again the divided tissues of the part by suitable buried sutures, so as not only to secure more perfect apposition, but also to obliterate 'dead spaces' in which blood-clot or effusion may collect. In this way wounds through fleshy and vascular structures may sometimes be closed completely without drainage. On the other hand, where accurate apposition of tissues and obliteration of cavities cannot be obtained, as after clearing out the axilla, and where some amount of oozing may be expected, it is always desirable to insert a drainage-tube or a 'cigarette' drain and stitch it flush with the surface. It is removed at the end of forty-eight hours at most; in such cases the removal of the discharge and the changing of the soaked and perhaps stiffened dressings add materially to the comfort of the patient.

When the operation has been completed, the skin around is cleansed with lotion, but *only after a piece of dressing has been placed as a protection over the wound.* This cleansing should always be accomplished by wiping peripherally away from the wound, and any swab utilized for this purpose should not again be allowed to touch it.

10. Finally, a carefully arranged **Dressing** is applied, and the part bandaged and placed at rest on a splint or in a sling, if such is indicated by the requirements of the case; absolute rest and quiet are essential if rapid healing is to be obtained.

Most surgeons, however, employ simple sterilized gauze without any antiseptic ingredients, and where complete asepsis has been maintained and no great amount of discharge is expected, this will suffice admirably. An antiseptic dressing is, however, an extra safeguard that may be wisely adopted, and especially in cases where a good deal of post-operative oozing is likely to occur.

11. **After-Treatment.**—If no drainage-tube has been employed, and the dressing is not soaked through, it may be left untouched for seven or eight days, at the conclusion of which period it is removed, the stitches are taken out, and in all probability the wound will be completely healed. When a drain has been inserted, it is usual to take it out at the end of twenty-four or forty-eight hours; there is no advantage in retaining it longer, since it is only required for the removal of the sero-sanguineous fluid which exudes immediately after the operation. Should this early discharge be very abundant and soak through the dressings, there is no actual need to remove them and re-dress during the first twenty-four hours, if cyanide gauze has been employed; all that should be done is to damp the stained external bandages with 1 in 20 carbolic lotion, and then pack on some more gauze or wool; this may even, if necessary, be repeated a second time. Where merely sterile gauze has been used, it is essential to re-dress the wound completely.

The **after-dressings** of the wound need to be conducted with the same precautions as to asepsis of hands, instruments, etc., as the original operation, and not a few instances of infection at the first dressing occur. It is essential that everything likely to be required

should be prepared before the dressings are removed, so that exposure to the air may last as short a time as possible. If the first dressing is undertaken after twenty-four or forty-eight hours, and all is going on satisfactorily, the drain is removed, and the wound re-dressed in exactly the same way as formerly, though probably much less gauze will be required. If the case is left for eight days, the stitches can probably be taken out, and the skin incision will then be found united. A small dressing of sterilized or cyanide gauze is applied, fitting closely to the scar, and sealed down with flexile collodion, which will not only prevent the gauze from slipping, but will also by its contraction serve to steady the parts. This should be covered with wool and a bandage, so as to support the parts, and may be finally removed at the end of another week.

An **open method** of treating certain operation wounds may sometimes be adopted with considerable advantage. Absolute hæmostasis is the first essential, and the wound must be completely closed without drainage. It is carefully dried and painted over with 2 per cent. solution of iodine in spirit. A sterilized towel may be placed around the part for the first twenty-four hours; but this may be discarded afterwards, and the wound is left uncovered, and merely painted daily with the iodine solution. In the case of children some arrangement of the bedclothes must be devised to keep their fingers away from the part. Hernia operations and similar wounds do excellently under this régime, especially in warm weather.

CHAPTER XI.

THE USE OF PHYSICAL AGENCIES IN SURGERY.

WITHIN recent years there has been so large a development in the application of various physical agencies in the realm of medicine and surgery that it is desirable to discuss their powers and application in one chapter, and we propose in this to treat of the use of massage, remedial exercises, heat, light, electricity, and radio-activity, etc.

Position.—It must be remembered that the surgeon's work is not completed when the immediate lesion for which he is responsible is repaired; his duties also extend to the subsequent period of restoring functional activity to the parts involved. Thus it is not enough merely to secure the union of a broken bone; it is the duty of the medical attendant to take such precautions as shall prevent, if possible, the limitation of movement in neighbouring joints, or to institute treatment for the removal of such stiffness, if it has unfortunately occurred. The excision of a cancerous breast is a beneficent operation, but the surgeon is doing no kind turn to his patient if he allows her to recover with an arm which is so fixed to the side that it can only be raised with pain and difficulty; a little forethought can prevent many a painful disability.

The prolonged fixation of a limb causes many changes which the surgeon must carefully study if harmful effects are not to be produced. In the first place the blood-supply suffers, and this may result in defective nutrition, and diminished resistance to bacterial infection. Muscles become stiff from want of use, and if the limb is the seat of hæmorrhagic extravasation due to traumatism or of septic inflammation, extensive fibroid infiltration may follow which it is difficult subsequently to remove. Volkmann's ischæmic contracture is probably of this nature. Joints are not seriously disabled by prolonged immobility unless intra-articular pressure due to weight-carrying or to muscular spasm is superadded, and then fibrosis of ligaments and thickening of the synovial membrane with the production of adhesions may result in limitation of movement, fixity in a bad position, or other troubles. Still more likely is this to occur if peri-articular inflammatory troubles of bacterial origin are in existence, or if the patient is suffering from any marked degree of toxæmia. Definite atrophy of bone also occurs when prolonged rest is maintained.

It is essential, therefore, that if a limb is to be fixed in one position for any length of time, that position shall be selected which will lead to as little subsequent disability as possible and shall permit rapid restoration of function when once the necessity for fixation has come to an end. It must be remembered as a cardinal principle that *it is*

always easier to relax a stretched muscle or tissue than to stretch one that is contracted; and hence if particular structures are liable to contraction which will be difficult to overcome, these structures should be put on the stretch during the period of immobilization. A few specific illustrations will be useful. (*a*) Prolonged fixation of the arm to the side is always liable to be followed by contraction of the pectoralis major and latissimus dorsi muscles, and much pain and discomfort have to be experienced before the arm is once again freely movable. This is likely to be aggravated in cases of axillary cellulitis or suppuration where cicatricial tissue has to develop between or in the substance of these muscles. In these cases the arm should always be kept at right angles to the trunk, as has now been the custom for some years in the post-operative treatment of scirrhus mammæ; it is then easy when the time comes to drop the arm to the side. If, however, there is a likelihood of osseous ankylosis occurring at the shoulder-

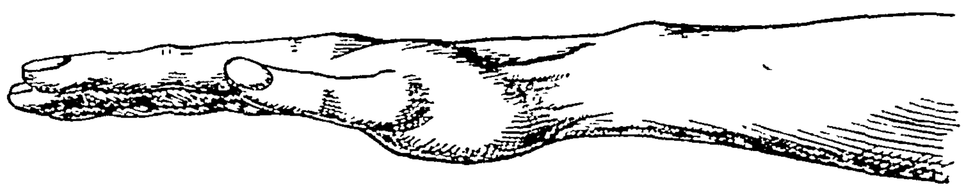


FIG. 113.—HAND IN WRONG POSITION FOR PROLONGED FIXATION.

FIG. 114.—HAND IN CORRECT POSITION FOR PROLONGED FIXATION.

joint, the arm must not be kept away from the side for more than about half a right angle. (*b*) Grave limitation of movements of the wrist and fingers is always liable to follow prolonged immobility of the hand. If it is kept on a splint in the position indicated in Fig. 113, it is obvious that the interossei are contracted, and it will be difficult to stretch them subsequently, whilst the flexor tendons are on the stretch, and thus liable to become adherent to their sheaths. Whenever possible, the fingers and thumb should be left unbandaged, so as to be free to move, and the wrist must be kept at rest in a slightly hyper-extended position on a 'cock-up' splint (Fig. 115). If the fingers and thumb must be immobilized, the position to be adopted must, if possible, be that indicated in Fig. 114, *i.e.* as if the patient were attempting to pick up a large ball. (*c*) In conditions involving prolonged fixity of the forearm, *e.g.* septic compound fractures of radius and ulna, the hand should be kept in a position of full supina-

tion; otherwise the supinators become stretched, fibrous and atrophied, the pronators are contracted, and subsequent supination (always the weakest movement of the forearm) becomes almost an impossibility. If, however, it is probable that subsequent rotation of the forearm will be entirely lost, the hand should be kept almost midway between pronation and supination, but with the palm turned a little upwards. (*d*) Whenever it is likely that the necessary development of scar tissue will lead by its inherent contractility to subsequent deformity, the limb should, if possible, be placed in a natural or even hyper-corrected position so as to allow for contraction; thus, in a septic transverse wound of the gastrocnemius fibroid changes occur which result in drawing up of the heel into an equinus position necessitating division of the tendo Achillis at a later date; this should be prevented by placing the limb on a splint, which maintains the foot at right angles.

Prevention of a deformity by the surgeon's forethought is always better than its cure by the most ingenious skill.

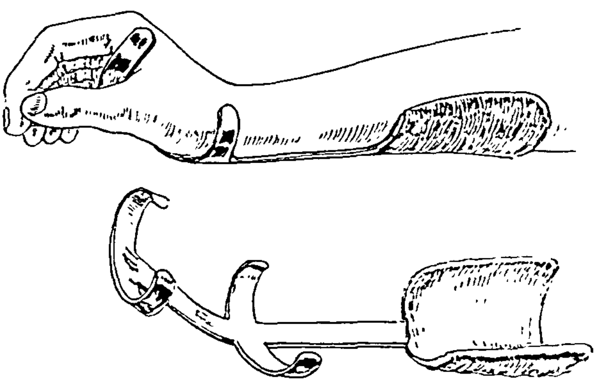


FIG. 115.—'COCK-UP' SPLINT FOR HYPER-EXTENSION OF WRIST.

Massage.—Massage, or the skilled rubbing of a part, is of the greatest value in many conditions, and has been employed to a great and increasing extent for some years past. All doctors and nurses should know something of massage from a personal and practical standpoint, but it is usually entrusted to specially educated and trained agents for its due performance, and one must refer readers to special textbooks if they desire to study fully its value and method of application.

The chief varieties of movement are known as effleurage, pétrissage, and tapotement. *Effleurage* consists in plain up and down rubbing of the limb with the flat of the hand, the up stroke being always firmer than the down, so as to assist in the return of the blood and lymph from the part. In this way the circulation is quickened, and the vital activities of the tissues are increased. The skin should be lubricated with oil, vaseline, or some stimulating embrocation, or dusted with oxide of zinc or talcum powder, and the rubbing, at first light, so as only to affect the skin and subcutaneous tissues, should gradually become firmer, so as to influence the deep structures. *Pétrissage* consists in kneading the muscles or other tissues between the finger-tips and the palm of the hand; this necessarily should be done across the muscle fibres, working from below upwards, and is especially valuable in hastening the absorption of exudations. In *Tapotement* a series of blows perpendicular to the surface is rapidly delivered by the ulnar side of the open or clenched hand; the circu-

lation in the parts thus struck is much quickened, and when skilfully done no pain should be caused.

As a modification of the last proceeding, *Vibro-massage* has been recently introduced, in which rapidly repeated blows of the affected region give rise to a vibratory effect, which is often of the greatest value. Hand vibrators are sold, and may be used with advantage; but the best results follow from the employment of vibrators worked by electricity. Rheumatic inflammation of joints and fasciæ, such as occurs in lumbago, some forms of sciatica, and other neuralgic conditions, are often much benefited by this procedure.

It is only possible to allude here to a few of the many conditions for which massage is beneficially used.

1. When applied lightly, and only dealing with the superficial parts, it is soothing in its effects and may be employed for the relief of pain; all hyper-sensitive areas should be treated in this way to commence with, not only to ensure comfort, but also to gain the patient's confidence. The lightest finger-tip massage (stroking) is most soothing, and its application to a patient's head and face late at night will sometimes assist in overcoming sleeplessness (as the writer can gratefully testify). It may also be employed to allay muscular spasm soon after a fracture.

2. Deeper massage of all types is valuable in assisting in the absorption of inflammatory exudates and in increasing the amount of healthy blood in a part. The driving out of the stagnant lymph and blood from the tissues prepares the way for a better supply of healthy blood, and thereby repair can be expedited. It is obvious, however, that massage must be sparingly employed where infective material is present, and might be dislodged or driven into the general circulation by injudicious manipulation. It is therefore more frequently employed in chronic affections, and only in the later stages of acute troubles.

3. It is largely used and extremely beneficial for its purely mechanical effects in freeing adherent tissues and restoring to them their power of independent utility. As a result of hæmorrhagic or inflammatory effusion, muscles get matted together, or fixed to bones, or perhaps all the tissues of a limb seem to be hopelessly welded into a solid mass, especially if it has been necessary to maintain prolonged rest after a septic injury, as in many gunshot wounds. In such cases, as soon as possible consistent with safety, massage should be commenced so as to free the parts from their intimate union with each other, and make them once again independent entities. Adhesions in tendon sheaths and joints may be largely influenced for good by suitable massage, but active movements under an anæsthetic to break these through are sometimes required.

4. Massage is of great value in many cases simply by increasing the blood-supply to the part, and thereby encouraging repair. Many a fracture which is slow in its progress and in which union is delayed may be hurried up by suitable massage, and sluggish wounds of all sorts may be stimulated thereby.

5. Deep organs may be affected equally with the superficial, and in

many abdominal conditions massage may be beneficially employed. Thus in chronic constipation massage along the course of the colon is often of more use than medicine, especially if combined with suitable exercises for employing the muscles of the abdominal wall.

6. General massage of the limbs and trunk is often ordered so as to maintain the general health of the body during a period of enforced rest. It thereby provides exercise without effort, and function without fatigue. Perhaps it is of most value in cases of nerve prostration when sleep and over-feeding are required to build up the tone of the nervous as well as of the physical system. Similarly local massage is employed to maintain the vitality and flexibility of parts that must be kept at rest for a long time, *e.g.* limbs with fractured bones or divided nerves.

Remedial Exercises.—There are limits, however, to the usefulness of massage as a remedial agent, for the effective restoration of the functions of muscles and joints can only be brought about by movement. There is but little doubt that in the past the medical profession has been unduly conservative and cautious in this direction, thereby playing into the hands of unqualified practitioners of the bone-setter type. Remedial exercises are both passive and active in character, and some little discrimination must be employed in the selection of suitable exercises in particular cases.

Passive Movements do not involve any great strain upon a part, and are to be employed at as early a date as possible. They are usually undertaken by a trained rubber, but any intelligent nurse can do what is required. All parts which do not require to be immobilized should be exercised in this way daily. Thus in a closed fracture of the forearm it is quite possible to move each joint of the fingers daily, and even with care the elbow and wrist; pronation and supination must be delayed until the bones are united, but in two or three weeks it is possible that this movement may be commenced. In a case of fractured clavicle passive movements of the elbow may be permitted from the first, and active movements of the fingers and wrist; but the shoulder and clavicular joints are kept at rest for about a fortnight, and then cautious movements are permitted. In inflammatory troubles of the hand and foot one cannot emphasize too strongly the necessity for early passive movements of all parts other than the chief focus of trouble.

When once stiffness of a joint has supervened, whether due to intra- or extra-articular causes (other than osseous ankylosis), it is often a matter of grave difficulty to restore mobility. It may be necessary for the surgeon forcibly to break down adhesions under an anæsthetic as a preliminary to further treatment, and then after a short interval to institute suitable exercises.

Active Exercises must replace passive movement as soon as possible so as to introduce the important element of will-power. In muscle re-education the limitations of the weakened structures must be respected, however, and an impossible strain must not be placed upon them. Thus in abducting the arm from the side the deltoid has not only to influence the humerus, but also to lift the weight of the arm—

often too great a task for a weakened muscle. If the patient is placed lying on a couch so as to support the weight of the arm, the deltoid can often effect the angular displacement of the limb into a position of abduction when it would be impossible to lift it in the standing posture. A similar suggestion applies to the knee; the quadriceps may be able to extend the leg if the weight be removed by lying on the outer side, whereas it is impossible at first to take the 'maximum load' by lifting the unsupported leg and foot. All re-educational exercises must take such facts into consideration.

Weakened muscles may at the same time be helped and toned up by massage, electrical stimulation (sinusoidal current), etc., but these are to be looked on merely as accessories.

Machines have been much vaunted as valuable helps in regaining movements of joints, and rightly employed they may be useful. Some machines provide passive movement alone, and merely replace a masseur by mechanism. Others introduce the principle of the fly-wheel, the continuous revolution of which will maintain and increase the movements of the limb which is attached to it. In still others the patient uses sound muscles to lift a weight by a rope passing over a pulley, and on letting it fall a contracted muscle may be stretched.

Active Exercises against Resistance are also much employed in order to tone up muscles which have lost power, and ligamentous or tendinous structures which have been damaged. The efforts are made either against the trained muscles of a masseur, or against the increasing friction of a machine. As the structure becomes stronger, the resistance is increased, so that finally the part may be safely exposed to the unlimited strains of normal life. This method of treatment is particularly valuable in dealing with the knee-joint after an operation involving ligaments; the strain of weight-carrying, especially if the patient is tall, is very severe, and until a full course of exercises against resistance has been given, the patient should not be allowed to walk.

There is an undoubted place for all these varieties of exercise, but they have their limitations, especially when a nervous defect is superadded to the muscular or articular lesion. The patient's will must be brought into action, as well as his muscles rubbed or his limbs moved by machinery, and in this direction **Active Exercises in the Gymnasium** under suitable supervision are of more value than many machines. It is impossible here to elaborate gymnastic methods, but a few general principles may be referred to.

1. It is useless to expect a patient to exercise one damaged muscle by itself. The associated action of a group of muscles, of which the damaged one is a member, should always be attempted, and the patient often uses the damaged part unconsciously when his interest is mainly concentrated on other things. Thus in re-educating the supinators, which frequently become very weak, it is better to teach the patient how to swing an Indian club than to set him to the monotonous task of rotating handles against resistance. The pendulum-like swing of the club is helpful, and the improvement of the general tone and vascularity of the whole arm is a most valuable asset.

2. Equally important is it to remember that bilateral movements are often more easily acquired than when only one limb is used, and effects are hereby often produced in a short time that previously seemed impracticable.

3. Not unfrequently it is possible to secure movements of joints by suitable games, in which the patient does not realize all that he is doing. For stiff arms and legs there is nothing much better than a game of skittles or bowling; if the patient is made to bowl the ball properly, most of the joints in the body are exercised.

4. One must insist, in conclusion, on the immense influence mind has over matter. The fact that some response is obtained to the efforts put forth is a great incentive to further effort; when a man's fingers have been kept stiff and rigid for a long time, it is a great thing when he realizes for the first time that he can impress and indent something with them. A useful plaything for this type of patient is the handbag or abacot, a leather-covered air cushion shaped like an Indian club. Constant handling of this contrivance gives the man's sensorium a feeling of satisfaction and confidence as his grip improves.

Heat (Thermo-Therapy).

Apart from its value as a sterilizing agent, heat is of use in treatment on account of the active arterial hyperæmia it produces, whereby the part to which it is applied is bathed with fresh blood containing defensive agents, such as leucocytes, opsonins, antitoxins, and other antibodies, by means of which the activities of harmful bacteria and their toxins are neutralized. Moreover, when applied to a part which is infiltrated and brawny, it assists in the restoration of a healthy circulation by softening and relaxing the tissues.

Heat is employed in two chief forms, *viz.* as moist or dry heat, and either may be utilized as a general or a local application.

1. **Moist Heat** is utilized *locally* in the form of the fomentation or poultice (p. 25), in order to assist an inflamed part to healthy repair. It matters little as to the material employed when the skin is unbroken, so long as it retains the heat, and, with this object in view, a linseed poultice is often preferable to a fomentation. When, however, there is an open wound, the fomentation or poultice must be aseptic at least, if not antiseptic, in character. The *boric fomentation* is useful in these cases, consisting of boric acid lint wrung out of boiling water, or a *carbolized poultice* may be employed. This latter consists of linseed-meal mixed with boiling carbolic lotion (1 in 60), and applied to the wound over a few layers of cyanide gauze.

Generally, moist heat is employed in the form of a *hot bath*, and, apart from its cleansing purposes, this is most valuable in many conditions and for varying purposes, *e.g.* to act as a sedative in cases of slight shock and general bruising of the body after accidents; to assist in the painless removal of extensive dressings which might stick to raw surfaces, such as burns, especially in children; to dilute toxins and help in their removal from the body, as in extensive infected wounds.

The *hot bath* is also used in various schemes of hydro-therapy in order to act upon many foci of chronic inflammatory trouble; *e.g.* in general muscular rheumatism and fibrositis the heat of the bath helps to relax and loosen the parts, and thereby to restore them to a healthy function. Plain water may be utilized for this purpose, or hot mud or peat baths. Massage of a portion of the body over which a stream of hot water, either in one large jet or from innumerable small ones, is passing constitutes the basis of the so-called *Aix or Vichy douche baths*, which are both pleasant and profitable methods of treatment for chronic inflammatory lesions of the fibrositis type. Active chemical substances, such as alkaline carbonates, sulphur, etc., naturally present in the water, or artificially added to it, are readily absorbed through the skin, and influence the patient considerably; natural mineral waters are probably more active than those artificially prepared. Alternating hot and cold baths are also of value in stimulating reparative changes.

2. **Dry Heat** may also be made to serve as a therapeutic agent, generally or locally, but in most instances introduces a new element, *viz.* diaphoresis as well as superficial hyperæmia. It is especially valuable in chronic cases, and, of course, higher temperatures can be borne without discomfort than in the preceding variety.

Generally, various methods of hot air or vapour baths are available. *Turkish baths* consist in the exposure of the unclothed body to dry heat at varying temperatures (up to 250° F. or more) for twenty or thirty minutes; by this means an abundant perspiration is induced, and thereby toxins are eliminated. It is followed by massage, douching, and rest for an hour or so, during which an abundance of plain cold water should be drunk. A *Russian bath* is very similar, but the air is full of the vapour of steam, and therefore cannot range so high; perspiration is induced more rapidly, and the bath is of shorter duration. In both of these agents the object is to induce the rapid elimination of toxins and other poisons, and at the same time to assist in maintaining the free mobility and function of the various parts of the body by massage.

In patients who are incapable of leaving their beds or homes, *e.g.* in cases of uræmia, or of very bad chronic rheumatism, hot-air baths may be given by covering the patient with a large cradle over which is placed a blanket or two, and under it, in such a way as not to endanger him, a lighted spirit-lamp or a suitable number of electric lights of sufficient power. Occasionally, however, wet packs have to be relied on in such cases.

Locally, there are many methods of applying dry heat to a part, of which the following are the chief:

(1) *Hot-air baths*, such as the Sheffield-Tallerman apparatus, etc., consist essentially of a box or chamber with walls composed of felt or asbestos, and arranged so that the contained air can be heated to a required temperature by an oil or gas burner or by electricity. The affected limb is introduced into the chamber through a window with a closely-fitting curtain, and carefully suspended to prevent the skin touching the hot walls.

(2) *Radiant-heat baths* have electric incandescent lamps as their heating agents. The therapeutic value of these baths depends not only on the hot air evolved, but also, and probably mainly, on certain light rays which have no heating power. A bath consists of a cabinet containing a number of lamps, which may have various-coloured globes, so that, by absorbing rays corresponding to certain portions of the spectrum, the quality of the light may be varied. They may be used for the whole body or for individual limbs.

(3) In *Diathermy*, or thermo-penetration, a high-frequency current of extremely rapid oscillation (about a million a second) is employed; the oscillations being so rapid and more sustained, the current can be passed through the body without pain, unless from over-heating of the tissues. The potential being high, the body offers resistance to its passage, and thus the temperature is raised along the track of the current, as when any other current passes through a resistance. The action of this agent therefore differs from that of hot-air baths, etc., in that the *internal* temperature of the part is raised rather than the external air, and hence the therapeutic results are increased. It is easy to localize the effects by the use of suitable terminals.

Applications.—Hot-air and radiant-heat baths are chiefly employed to promote the absorption of chronic inflammatory exudates, and for such conditions as chronic arthritis, adhesions, neuralgia, lumbago, and sciatica. They are also used to aid elimination by determining diaphoresis in general toxic conditions, such as gout, Bright's disease, and obesity. Diathermy is useful for chronic inflammation, osteo-arthritis, rheumatic and gouty fibrositis, as also in gonococcal lesions.

Heat is of great value in preventing or counteracting shock. The importance of keeping a patient warm during a lengthy operation has been emphasized more than once, and to this end operating rooms are now maintained at a high temperature (70° to 80° F.) and the patient is carefully clothed. To combat the shock which follows operations or serious injuries, such as bad burns, especially in children, when the patient's temperature often falls as low as 95° or 96° F., it is important to surround the body with air at a higher temperature; and this can be effected by covering him with a cradle over which a blanket is placed, merely leaving the head uncovered, and within which is placed an electric lamp of 50 or 100 candle-power, so that it cannot touch or be touched by the patient's limbs. The result of this hot-air bath is often most valuable.

Cauteries are employed in the application of heat to the tissues of such an intensity as to burn them. Their uses in this direction are twofold:

1. As a *counter-irritant*, with a view not only to affect indirectly the underlying process of disease, but often rather to assist in the diminution of pain. Thus a painful joint or spine can be beneficially influenced by searing lightly the overlying skin. Some resistant forms of neuritis can be improved by this means.

2. More often cauterization is employed as a *hæmostatic* agent. Small bleeding points in situations difficult to reach or to control may be effectively dealt with in this way, *e.g.* in the nose, or where small

vessels in dense scar tissue are difficult to secure. Vascular tissues can be divided by this means without loss of blood, and at the same time the tissues involved are made or preserved aseptic. It is well to remember that a dull red heat is the most effective, since thereby the vessels are seared and closed; a cautery at a white heat cuts almost as cleanly as a knife. The possibility of secondary hæmorrhage when the slough separates must not, however, be forgotten.

The following are the chief forms of cautery ordinarily employed:

1. *Actual cauteries*, which consist of solid irons of various shapes, which are heated in a suitable flame to a temperature depending on the use for which they are required.

2. The *galvano-cautery* consists in a loop of platinum wire mounted on an insulated handle, and connected with the terminals of a battery of sufficient strength. The handle is fitted with a key, so that the current may be opened or closed at will. During the passage of a sufficiently strong current (5 to 6 amperes for small loops) the platinum becomes red or white hot. This form is of most use for dealing with small bleeding points or for the removal of pedunculated growths, such as polypi.

3. *Paquelin's thermo-cautery* depends on the principle that, when the vapour of benzoline is driven over heated platinum, its combustion generates sufficient heat to maintain or increase the temperature of the platinum. By means of a rubber bellows, air is driven over the surface of benzoline contained in a bottle, and then, saturated with its vapour, through a hollow handle into a platinum point. The platinum point is previously heated to a dull redness in a spirit flame, and on pumping the mixture through the apparatus it can be kept at a red or white heat.

4. The *diathermic cautery* is based on the use of the diathermic current, as described above. If one terminal is large and indifferent, it may be applied to arm, leg, or trunk without producing localized effects; if the other terminal is small, the current will be concentrated, and along its line of application the tissues will be heated to such a degree as to coagulate and destroy them. The active electrode may be varied in shape to suit the requirements of the case, and thus with a strong current and a small cutting terminal tissues can be excised and cauterized at the same moment, and thus hæmorrhage prevented. Malignant growths of the mouth, including tongue, tonsil, or pharynx, excision of which would be followed by severe bleeding, can often be safely dealt with by this agent, as also papillomata, etc., of the bladder. Wounds produced by this form of cautery heal quickly and without pain.

The electro-surgical unit (Davis-Bovie) is perhaps the most important addition that has been made to the surgeon's equipment during the last ten years.

The apparatus (Fig. 116) has a two-circuit design with separate transformers, condensers, coils, and spark gaps for each circuit. Both the cutting and coagulation currents are made to operate at the peak of effectiveness. Such a unit is invaluable to the neuro-surgeon who makes use of the coagulating current to stop bleeding from vessels in

the membranes of the brain or from cortical vessels. An important feature in using such a high-frequency current is that the rate of interruptions is so great that no stimulation to the nerve-cells is produced. In the treatment of brain tumours electro-surgery may be used to gouge out the centre of large tumours, and so collapsing them, leaving simply a shrivelled capsule.

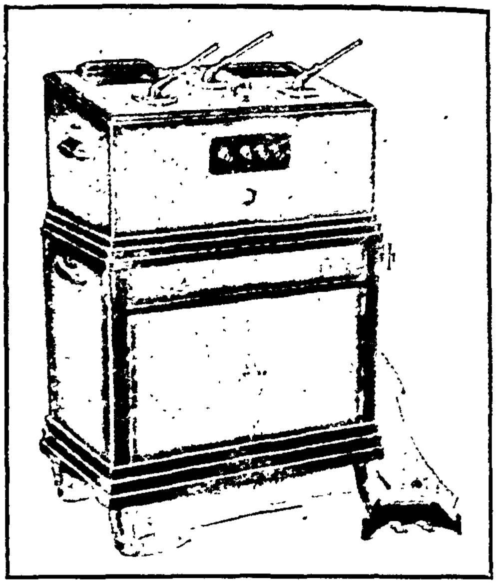


FIG. 116.—THE DAVIS-BOVIE ELECTRO-SURGICAL UNIT.

Transurethral resection of the prostate gland can be performed with this unit on many patients who could not stand an open operation. Bladder papillomas can be removed through a cystoscope by desiccation if small, and by coagulation in the case of larger growths.

The electro-surgical method of severing adhesions in artificial pneumothorax is superior to any other.

Radical breast operations may be performed with an endotherm knife, and often without the use of ligatures. The vessels are picked up with pressure forceps,

FIG. 117.—PHOTOGRAPH SHOWING THE METHOD OF USING THE ELECTRODE IN STOPPING HÆMORRHAGE.

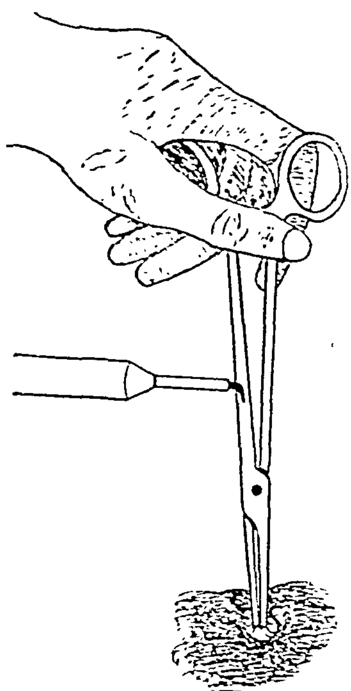


FIG. 118. — METHOD OF APPLYING ELECTRODE TO PRESSURE FORCEPS.

and these are touched in turn with the electrode (Figs. 117 and 118). On account of sparks taking place when coagulation is being used

the utmost caution must be exercised when using ether anæsthesia. It is much better to use gas and oxygen in these cases.

It may be said that electro-surgery is now extensively used, not only in general surgery, but in gynæcology, in eye, ear, nose and throat conditions, and in dermatology.

Light.

Light as a curative agent, apart from its thermal effects, is chiefly employed in the form of (1) the arc light, (2) Finsen and mercury vapour lamps, and (3) sun-baths.

1. The light from an *arc lamp*, projected by means of suitable mirrors, can be employed as a general bath or locally to diseased tissues. Whilst it contains a sufficiency of heat rays to necessitate caution when focussing it upon a part, its activity mainly depends on the presence of an abundance of *ultra-violet rays* similar to those in normal sunlight, and thus it is sometimes termed *artificial sunlight*. It may be employed for all conditions, local or general, for which direct heliotherapy is advised, *e.g.* tuberculous disease, lupus, rickets, and many types of malnutrition. Pigmentation of the skin is produced in exactly the same way as from exposure to sunlight, and the precautions needed in heliotherapy must be adopted.

2. The Finsen and mercury vapour lamps are methods of exposing small areas of disease to large doses of light containing an abundance of chemically active rays. A *Finsen* lamp consists of a powerful arc, the rays of which are collected and focussed by quartz lenses on a small area of skin, which is cooled and rendered anæmic by a quartz compressor, through which a stream of cold water flows. Compression aids the penetration of the rays by rendering the part bloodless, the blood having the power of absorbing the violet rays. The *mercury vapour* lamp consists of a glass tube exhausted of air, and containing mercury and mercury vapour. The passage of a suitable current through this produces a light rich in ultra-violet rays. These lamps are chiefly used in the treatment of lupus.

3. *Heliotherapy*, or exposure to the sun's rays, has already been referred to as having beneficial results in the treatment of tuberculous lesions, whether applied locally or to the whole body, and its effects and the precautions which need to be taken therewith have been indicated. It must not be overlooked that an element of aerotherapy usually enters into the cure produced by this means; sunshine and fresh air join hand in hand to promote the physical welfare of mankind.

Apart from tuberculosis, sunlight is of great value in cases of anæmia, rickets, and malnutrition, and also has a distinctly beneficial influence on the treatment of open wounds, which are stimulated to increased activity. All that is needed is to protect the surface with a layer of sterilized gauze. Sometimes the sunlight is so active as to cause considerable irritation, and it is unusual for a wound to be able to stand more than twenty to thirty minutes a day of this treatment.

The fact that normal sunlight is a complex of varied coloured rays has not been forgotten, and the influence of the different elements of

the spectrum has been exploited. It is probable that exposure of the body to different coloured lights has a definite effect, especially to individuals of a receptive temperament. Green light appears to be soothing, red to be stimulating, and even irritative, and blue depressing. Neurasthenic patients with irritable hearts and constitution may be soothed, stimulated, or depressed by exposure to varied lights, and a definite therapeutic result may be expected.

Electricity.

Electricity, apart from its thermogenic power, has many important applications in the domains both of diagnosis and treatment.

1. **As a Diagnostic Agent.**

(1) By means of the *faradic and galvanic currents*, the electrical response of muscles and nerves can be investigated and valuable information obtained as to the condition of the nervous and muscular systems.

A muscle with a normal nerve-supply contracts under stimulation from both the faradic and galvanic currents in sufficient strength, the contraction being most readily obtained when the electrode is applied over a definite skin area, varying for every muscle, and called the 'motor point.' With the galvanic current the contraction obtained when the current is closed is greater than that produced when the current is opened. Again, the contraction elicited when the electrode applied to the muscle is attached to the kathode of the battery is greater than that resulting when the anodal electrode is used. This fact is expressed in the formula —K.C.C. >A.C.C.

In the muscular degeneration which follows nerve injuries, neuritis, anterior poliomyelitis, etc., these reactions are modified, and constitute the *reaction of degeneration* (R.D.). The response of the muscle and nerve to the faradic current quickly disappears, and with the galvanic current the anodal closure contraction becomes greater than the kathodal (A.C.C. >K.C.C.). A greater strength of current will be required than in the sound side of the body, and the response will be sluggish, and not brisk. As long as the R.D. persists, however, the possibility of repair in the muscle remains, should the centres and conducting apparatus be restored. This persistence of the R.D. may exist for years. When once the R.D. is lost, all hope of repair is gone. In spastic conditions the electrical irritability of muscles and nerves is often increased.

It is most desirable that muscles and nerves should be treated on a standardized scale, inasmuch as the results naturally vary somewhat with the strength of the electrical stimulus. To this end *condensers* have been introduced, whereby it is easy to regulate the strength of the current, and to state in simple and obvious terms the result of the test.

(2) *Radiography*.—When a current from the secondary circuit of an induction coil is passed between two suitable metal electrodes in a vacuum tube of a high degree of exhaustion (Crooke's tube), a stream of rays, called 'kathodal' or 'β-rays,' which consists of negatively charged electrons, is generated from the cathode. If the kathode is concave, and the rays are thereby made to converge to a focus on

a third electrode called the 'target,' or 'antikathode,' from their impact thereon results a production of rays of a very special character, known as the 'X-rays of Röntgen.' X-rays have the power of penetrating most opaque bodies in varying degrees, and in general terms substances are opaque to X-rays in proportion to the atomic weights of their constituent elements. X-rays also have the power of acting upon sensitive silver salts in the same way as light, so that if a structure, such as a limb, be interposed between the source of the rays and a sensitive photographic plate, the rays will readily penetrate the softer parts; but their passage will be hindered by the more resistant structures, such as bones, which will thereby throw a shadow on the plate. Radiograms or skiagrams are the shadow-pictures produced in this manner. The greater the vacuum in the tube, the greater will be the strength of current needed to traverse it, and the greater the penetrating power of the X-rays produced. These are known as 'hard tubes.' Soft tubes are those in which less strength of current is required to produce the rays, which have a less penetrating effect, and therefore are more useful in permitting a greater differentiation of shadow.

Barium platino-cyanide and certain uranium salts are rendered fluorescent by the passage of X-rays, so that, if a screen covered with one of these substances is held distal to the limb or part to be examined, a shadow similar to a radiograph is produced and can be seen. The *radiographic screen* is of great value in many conditions as a means of rapid diagnosis, and sometimes gives better results than the radiograph, especially when absolute immobility cannot be obtained. Thus the movements of the heart, of the diaphragm, the pulsations of an aortic aneurism, etc., can be better examined by the screen than by taking a radiograph. As an illustration of this may be mentioned a case where a silver probe had slipped down through a tracheotomy wound into a bronchus. An attempt to photograph it failed completely, but on examination with the screen the probe was seen lying transversely in the left bronchus, moving up and down at each beat of the heart.

Great care is necessary in the interpretation of radiographic pictures, as, the rays being divergent, some distortion of the resulting shadows occurs, according to the distance of the object from the source, and the exact angle at which the rays impinge upon it. To avoid this deception, stereoscopic photographs, or views in two directions at right angles to one another, are necessary. Moreover, the results vary much according to whether the radiograph is taken from before or behind. Thus, if a shoulder is radiographed from behind, the details of the coracoid process and of the head of the humerus will be most clearly defined; whereas if the plate is posterior, and the picture is taken from the front, the acromion and spine of the scapula are more sharply represented. In practice the outlines of bones are clearly seen; cartilage and callus are often transparent; muscles and tendons are sometimes visible if a very soft tube is employed. Calculi vary according to their composition, oxalates being most opaque, and uric acid stones most transparent. Gallstones are seldom impervious (12 per cent.

visible). By the use of soft tubes the outlines of viscera, such as the liver and kidneys, may often be obtained.

In the case of foreign bodies it is not sufficient merely to know that they are present in a particular locality. Every operating surgeon knows the difficulty of finding them, and the most serious damage has often been inflicted in the soft parts by attempting their removal on insufficient data. The *exact localization* of foreign bodies is now easily determined by many methods which it is impossible to describe here, but every expert radiographer can give the surgeon invaluable assistance in this direction, and no operation for the removal of a foreign body embedded deeply in muscular tissues, and hence impalpable, should be undertaken without this exact information being previously obtained. Even more help is available from the use of the radiographic screen during the operation, by the use of which it is possible to see the foreign body during the manipulation necessary for its removal.

In the localization of brain tumours, air may be injected into the lateral ventricles (ventriculography) (see Chapter XXVII.).

It often suffices to take radiographs in two directions, *e.g.* antero-posterior and lateral, and by a careful comparison of these sufficiently satisfactory data are obtained to enable the surgeon to find the foreign body.

For the employment of X-rays in fractures, see Chapter XX.

2. As a **Therapeutic Agent** electricity is employed in many ways:

(1) The *galvanic and faradic currents* are employed, both generally and locally, for their stimulating action. Under the former heading one would include the use of the *electric bath*, in which a patient lies in water to which a small addition of salt is made, and through which a galvanic current is passed. The effect of this is to increase the superficial circulation and produce cutaneous hyperæmia. It is often useful in diffuse rheumatic and gouty fibrositis, as also in conditions in which the general muscular and nervous tone of the body has been lowered. It is of considerable value in the treatment of conditions depending on arterial spasm, such as Raynaud's disease, as also to prevent chilblains in paralyzed limbs. Care must be taken only to increase or decrease the strength of the current gradually, otherwise the patient may experience an unpleasant shock.

Locally the galvanic and faradic currents find their chief employment in cases of muscular paralysis or wasting, both to prevent degeneration or atrophy, when nervous control has been lost, as by division of the motor nerve, and to build up healthy muscular substance after nerve-suture or when atrophy has occurred from disuse. The *sinusoidal* current is perhaps the most useful to employ in the earlier stages; in this the current is continuous, but is made to vary in strength in a smooth and wave-like fashion without sudden interruptions. Later, the *interrupted galvanic* current is more useful, and is often the only one to which response can be obtained, whether before operation or in the earlier stages of repair. The current must be made and broken at regular intervals, a metronome introduced into the circuit being a useful contrivance. Failing this, the patient may be instructed

to remove and replace one of the terminals at regular intervals, thereby stimulating his interest in his own case. When once response is obtained to the faradic current after an operation for nerve-suture, this type of electricity should be substituted for the galvanic current as being more effective.

(2) *Electrolysis* is used chiefly for the destruction of superfluous hairs, moles, etc., and the treatment of nævi, where excision is undesirable. The passage of a current of sufficient strength between metallic poles actually inserted into the tissues sets up an electrolytic action, and coagulation of the blood or local destruction of hair follicles, etc., results.

(3) *Static electricity* generated by a machine such as Wimshurst's or the *high-frequency current* is used in the treatment of neurasthenia, general or nervous debility, or neuralgia, but is of value rather as a general tonic than as having any specific effect.

(4) *Ionic medication*, or cataphoresis, consists in the introduction of drugs directly into the tissues of the body by means of an electric current. It is based on the principle that the passage of a current through a solution of a salt is accompanied by movement of the constituent ions. The positively charged ions (kations), which include those of all metals, alkalies, and alkaloids, are attracted to the negative pole, while the negatively charged ions (anions), such as those of chlorine, iodine, the acids, and hydroxyl, are attracted to the positive pole. If the human body is interposed in the current, instead of a solution of salt in a vessel, and lint pads, soaked in a solution of the salt or drug, are placed between the skin and the electrodes, kations at the positive pole and anions at the negative pole will enter the tissues and be disseminated in them for a variable distance, probably from 1 to 10 millimetres. The pads should be thick and of large area, and the strength of current 2 to 3 milliamperes per square centimetre of area of the pads.

Ionization is largely used in the treatment of chronic inflammation of joints and other tissues and in the softening of scars, but good results have also been obtained in sinuses, chronic ulcers, rodent ulcers, lupus, warts, etc.

(5) The *diathermic current* has already been mentioned as employed as a means of heating the tissues (thermo-penetration, p. 297) or as a cauterizing agent.

Radio-Therapy and Radium.

Soon after the discovery of X-rays by Röntgen in 1895 it was found that they were capable of setting up severe dermatitis, often accompanied by ulceration, and also had a considerable depilatory power. The question therefore arose whether they could not be employed therapeutically in certain skin diseases requiring either a stimulative or depilatory action, and in no long time sundry cases of lupus were found to benefit by treatment. A large amount of experimental work quickly followed to determine the action on various tissues and organs.

It is now well known that repeated exposures may lead not only to dermatitis and X-ray burns, but also under certain conditions to the development of actual neoplasms; blood changes of a serious type

also follow. The genital cells are found to be remarkably susceptible to the action of the rays, the germinal cells of both testis and ovary being easily and permanently damaged, with the subsequent production of sterility. Upon the lining cells of the intestinal mucosa X-rays also have a powerful destructive effect, with the production of severe enteritis. From these facts it is evident that radio-therapy must invariably be carried out with due regard to the safety of both patient and operator.

It may be mentioned here that X-rays have now been proved to be electro-magnetic vibrations, similar in character to the Hertzian waves, heat waves, the rays of visible light, and the ultra-violet rays, though of shorter wave length. The respective wave lengths expressed in Ångström units* are:

Visible light ...	7,200–4,000 A.U.	The shorter the wave length,
Ultra-violet rays	4,000– 200 A.U.	the greater the penetrating
X-rays	500– 0·06 A.U.	power.

It was soon noticed that the parts chiefly affected by X-rays were the face and eyes and dorsum of the hands. In the latter the effects were sharply delimited by the coat cuffs, showing that the clothing had in some way acted as a protective agent, although upon examination either by the fluorescent screen or by means of a photographic plate the clothing appeared to be quite transparent to the rays. It is now known that the clothing acts by cutting off the rays of longest wave length, which at the same time are the least penetrating and the most active in producing changes in living tissues.

The Pastille Dose.—The fact that undue exposure to the rays produces serious results upon the skin has made it essential that some means of gauging the dose given should be available. For this purpose the *Sabouraud pastille* is sufficiently accurate and is easy to use. It consists of a paper disc coated on one side with barium platinocyanide. This, in its normal condition, is of pale apple-green colour, but with exposure to X-rays it passes through a gradation of tints until it becomes brown. The amount of exposure which just results in a definite erythema also produces a given brown tint in the pastille, and this is known as a pastille dose and is taken as the unit of dosage. The exposed pastille is compared with a series of tinted pieces of glass in a tintometer, estimated to represent one-fourth, one-third, one-half, etc., of a pastille dose.

It must be clearly understood that this method, though convenient, is not scientifically accurate, since the 'softer' (less penetrating and with longer wave length) rays are more active in producing this colour than are the 'harder' (more penetrating and with shorter wave length) rays. Needless to say, the Sabouraud pastille is useless to estimate the dosage of the very penetrating X-rays used in deep therapy. For practical purposes screens of aluminium are usually placed between the X-ray tube and the patient, so as to cut off more or less of the softer radiations; they vary in thickness from 0·5 up to 6 or 8 mm. of aluminium.

* The Ångström unit (A.U.) $= 10^{-8}$ cm. $= \frac{1}{100000000}$ cm.

One of the dangers in connection with X-ray therapy is that its effects upon the skin are not apparent at once; a certain latent period elapses between exposure and any obvious change, varying with the conditions and individual, but is generally from a week to fourteen days. If, therefore, a skin surface is irradiated, and the dose repeated before the time has elapsed for the former dose to have produced a reaction, a cumulative effect will result. A single exposure to an overdose may result in anything from a slight transient erythema to a deep, painful, and slowly healing ulcer. Continued exposure of an area which has already been the seat of an X-ray burn may lead to the development of a definite carcinoma.

Among the lesser evils which affect the patient more than the operator are the production of bronzing and the formation of telangiectases, but these are largely due to idiosyncrasy. Some patients undergo repeated exposures, *e.g.* at the site of an old mammary carcinoma, or on the neck for Graves' disease, without any marked result of this type; others, on the contrary, rapidly acquire a deep brown pigmentation, or a network of telangiectases may form. Whenever a slight erythema appears after irradiation, a soothing calamine lotion should be applied, and indeed in many places this is used as a routine preventive measure. It must, however, be remembered that this lotion or any application containing metallic salts must be thoroughly removed before the part is again irradiated, owing to the production of what are known as secondary radiations, when a beam of X-rays impinges upon them. These secondary rays are of longer wave length than the primary, and may therefore have a destructive effect upon the tissues.

The methods of applying X-ray radiation therapeutically may be broadly grouped into two main divisions according to the kilowatt voltage. **High Voltage Therapy** (400 to 200 kilowatts) is the type employed for deep therapy, and the best results by this method are seen in connection with the treatment of carcinoma of the breast, in conjunction with surgery, and of glandular neoplastic deposits when these are accessible, as in the neck. A dosage of 6,000 'r' units is aimed for, but is not always given when large areas have to be treated, as in the case of the breast. In such cases a reduced dose of between 4,000 and 5,000 'r' units would be employed. **Low Voltage Therapy** (50 to 60 kilowatts) is useful for all types of superficial malignant disease, and therefore is most commonly employed in the treatment of cancer of the skin, mouth, and bladder, when a supra-pubic opening in the latter is available. The tube conveying the radiation must be almost touching the lesion, and the field should cover an area of between 3 and 5 cm. In appropriate lesions this type of radiation is most effective. It is sometimes referred to as the Chaoul type of therapy, after the name of the worker who was the first to make use of it.

Radium.

Radium salts were first isolated from pitch-blende by Madame Curie in 1898, but the radium element itself not until 1911. The radium salts commonly used are the sulphate, bromide, and chloride.

The chloride and bromide are soluble in water; the sulphate is insoluble, and is the salt generally used for filling radium apparatus, as its insolubility is an obvious advantage in the event of any minute perforation occurring in the applicator.

Radium itself is a metallic element belonging to the group of radio-active substances. It undergoes spontaneous disintegration, and breaks up into a number of unstable atoms. As each change takes place, energy is lost by the substance and appears as a characteristic type of radiation. The activity of radium, and therefore its therapeutic effects, are due to a number of disintegration products.

Radium transforms slowly compared with most radio-active bodies. About half the atoms of an amount of radium are transformed in 1,700 years. The first disintegration process leads to the production of radium emanation or radon, a heavy gas, used widely in therapy.

The radiations liberated during the process of disintegration of radium are complex, but have been recognized as falling into three groups—α, β, and γ rays. It is estimated that of the total energy emitted 90 per cent. is attributed to the α rays, 9 per cent. to the β rays, while the gamma rays are responsible for only 1 per cent.

The α rays are composed of doubly charged helium atoms which are emitted with a velocity equal to one-twentieth part of the velocity of light. Their penetrating power is, however, exceedingly small, since they are stopped by a screen such as a sheet of paper. They are, therefore, of little therapeutic use, as they will be stopped by outermost layers of the tissues.

The β particles are electrons or unit charges of negative electricity associated with a mass of $\frac{1}{1850}$ that of a hydrogen atom, and with a velocity almost as great as that of light. Roughly speaking, they may be regarded as having a penetrating power about a hundred times as great as that of the α particles. They are, however, screened off by relatively thin layers of various metals. In soft tissues the β rays penetrate to a distance of 1·5 cm. Consequently, in actual practice the beta rays are used only when dealing with lesions of the skin not greater than 1·5 cm. in depth.

For most surgical purposes, therefore, the β radiations are purposely cut off by metal screens of suitable thickness. The thickness of different metals necessary to screen off 50 or 99·9 per cent. respectively of β rays may be summarized as follows:

Substance.	*Thickness Necessary for Absorption of—*	
	50 per Cent. Radiations.	*99·9 per Cent. Radiations.*
Monel metal	0·15 mm.	1·5 mm.
Silver	0·13 mm.	1·3 mm.
Lead	0·12 mm.	1·2 mm.
Gold	0·07 mm.	0·7 mm.
Platinum	0·06 mm	0·6 mm.

The γ rays are electromagnetic waves similar to X-rays and ultra-violet rays. Their velocity is the same as that of light, but their wave length is much shorter than that of X-rays. The length of the wave determines the penetrating power of the ray; the shorter the wave length the more penetrating the ray. The most penetrating rays are called the 'hard' rays, and the less penetrating the 'soft' rays. According to measurement, it takes about 16 cm. of lead to absorb the most penetrating gamma rays.

It is the γ rays which are mostly used in radium therapy, and that because they appear to have a selective action in destroying malignant cells more readily than the normal cells of the body. This selective action is most marked in the 'hard' γ rays, and for this purpose the screenage is often increased.

As we have seen, a screen of 0·6 mm. of platinum cuts out 99·9 per cent. of the β radiation; at the same time, however, it also cuts out a proportion (about 6 per cent.) of the γ rays. With increasing thickness of platinum the proportion eliminated is increased, while the proportion allowed to pass comprises the rays of greatest hardness or shortest wave length. *Secondary radiations* are produced when the γ ray is stopped by an object. These have a penetrating power equivalent to that of the β rays. In practice, screens of lead and platinum are used, and the secondary rays given off at the surface of such a screen produce a destructive action of the tissues in immediate contact. This effect is well seen in the necrosis which takes place round a radium needle buried in the tissues.

As regards the form of radium applicators for surgical lesions, these often take the form of flat applicators of different shapes and sizes, adapted to the purpose for which they are intended.

Containers for surgical use are mostly made in the form of hollow needles with a wall thickness of 0·6 mm. of platinum-iridium alloy.* The measurement of such needles is always made in terms of radium element, and all are made to have a definite distribution of radium per centimetre active length. The needles generally used at present contain 0·5 mgm. per centimetre active length. The point and eye of the needle are solid and therefore inactive. A 1 mgm. needle is approximately 3 cm. long, the active length being 2 cm. and the inactive ends measuring 1 cm.

Tubular containers can in many cases be used as flat applicators by suitably placing a number of them side by side, mounted according to circumstances on sorbo rubber or Columbia paste† of 1 to 2 cm. thick. They may also be mounted on a plate or denture of dental wax for intra-oral application in cases of carcinoma of hard palate or alveolus.

Radium emanation, or radon, the radio-active gas given off from radium, is used widely in therapy, since its disintegration leads to the production of the α, β, and γ rays. It is impossible to deal here

* *I.e.* platinum to which 10 per cent. of iridium is added to increase the durability, hardness, and rigidity of the tubes. Pure platinum bends too easily, and is therefore not convenient for surgical purposes.

† Columbia paste consists of a mixture of beeswax, paraffin, and fine sawdust.

with the subject of atomic disintegration and the types of radiation emitted during its various phases. Suffice it to say that for obtaining radon for therapeutic purposes a soluble salt of radium (the chloride or the bromide) is dissolved in acidulated water and the resulting radio-active gas (radon) pumped off and purified in a suitable apparatus, whence it can be collected and sealed off in suitable capillary glass tubes. These small capillary tubes are then inserted into metal cases of platinum or gold with a screenage of 0·5 mm., and are known as radon 'seeds.' The object of this screenage is the elimination of β radiation, and the consequent avoidance of the necrosis, sloughing and pain which attend the action of β radiations upon the tissues. The 'seeds' may be implanted into a tumour and left, as they later become inert foreign bodies and thus do no harm (Fig. 119). Threads

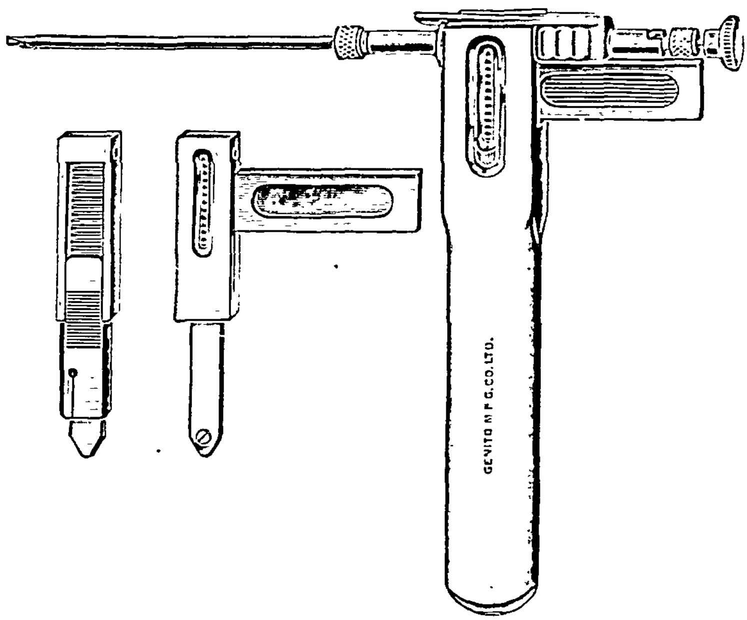


FIG. 119.—SEED GUN FOR INTRODUCING RADON SEEDS INTO TUMOURS.

may be attached to the 'seeds,' so that they may be withdrawn in seven days. The usual length of 'seeds' is 0·6 cm., and they contain from 1 to 2 millicuries of radon.

For the preparation of radon for therapeutic purposes, a relatively large quantity of radium salt is necessary. At the Medical Research Council's radon centre at the Middlesex Hospital about 1 gramme of radium bromide is used, as smaller quantities are not of much practical use for the purpose. The radium salt, when being used for the production of radon, can obviously not be put to any other use. Another point to be borne in mind in connection with the employment of radon is that the activity of the containers becomes progressively reduced through the constant loss of emanation from permeation. This progressive diminution of activity proceeds at a definite rate, and it is known that the strength of the containers is reduced by

50 per cent. at the end of 3·85 days, and by 75 per cent. at the end of 7·5 days. At the end of ten days the seeds contain only 16·5 per cent. of their original value. Thus, when the seeds are to be removed in any particular case, it is usual to do so between the seventh and tenth days.

Teleradium Therapy, or '**Bomb**' treatment, involves the use of 1 to 5 grammes of radium at a distance of 6 to 8 cm. from the skin. With this treatment deep penetration is obtained, and by directing the beam through several ports of entry, a lethal dose can be delivered to the tumour with a minimum of skin reaction.

The filtration used in the 'bomb' is 4 mm. of platinum, and thus only the hard gamma rays are allowed to pass and a more selective action obtained.

Severe constitutional symptoms are likely to arise during the 'bomb' treatment of advanced malignant disease, as the blood-count diminishes rapidly. Hence, it is essential during treatment to do frequent blood-counts, especially white cell-counts, as this is first affected, a leucopenia resulting. The great danger in 'bomb' treatment is overdosage, which leads to tissue necrosis. The irradiated tissues break down into a painful ulcer which is very intractable, and may lead to death of the patient.

Those cases which are best treated by means of the 'bomb' are carcinoma of the larynx, pharynx, and mouth. It is the ideal treatment for carcinoma of the posterior third of the tongue and the floor of the mouth, as the primary growth and glandular areas are treated at the same time. The treatment lasts about six weeks, two exposures of three-quarters of an hour being given daily. The results obtained by 'bomb' treatment in these selected areas are much better than those obtained by surgery or interstitial radium.

The 'Bomb.'—This type of apparatus is no more than a container for a large quantity of radium stored in such a way that it is available for high dosage treatment of cancer with the minimum of radiation risk to worker and patient. The essential feature of this apparatus consists of a curved pipe fitted with a special type of nozzle. The unit is mounted on ball-bearings in a trunnion fitted to a vertical shaft hanging from the ceiling, and the whole apparatus is counterbalanced so that it can be raised, lowered, and rotated with the minimum of effort. In this way accurate and simple adjustment of the nozzle to the patient can be made. The radium is contained in a number of tubes packed inside a steel bobbin. The bobbin can be blown into position within the unit by air-pressure through a flexible pipe which conducts it from a lead storage safe, and it can be restored to the safe by reversing the air current. Protection of the manipulator is obtained by means of rings of a tungsten alloy fitted within the unit (Fig. 120).

Dosage.—For many years dosage has been expressed in terms of milligramme hours or of millicuries destroyed. This is obtained by multiplying the number of milligrammes of radium by the number of hours during which treatment is given. However, this result is misleading, as the effect of applying 50 mgm. of radium for one hour

is not the same as applying 1 mgm. for fifty hours, although the dose in milligramme hours is the same in each case. It is essential also to give details of filtration, the number of needles, the distance from the source, and the size of the field if the dosage in terms of milligramme hours is to be of any value.

This type of dosage is not, however, fully satisfactory, as it does not permit an accurate assessment of the amount of radiation given in any particular case, nor allow an exact gauge or comparison of the effects of treatment by other types of radiation. For this reason a uniform standard of dosage based on the 'r' (Röntgen) unit has been recommended and generally adopted. Its value is that it can be applied in the calculation of dosage with all forms of radiotherapy. The 'r' unit may be defined as that quantity of radiation which, under certain standard conditions, produces a conductivity such that the saturation current is equal to one electrostatic unit.

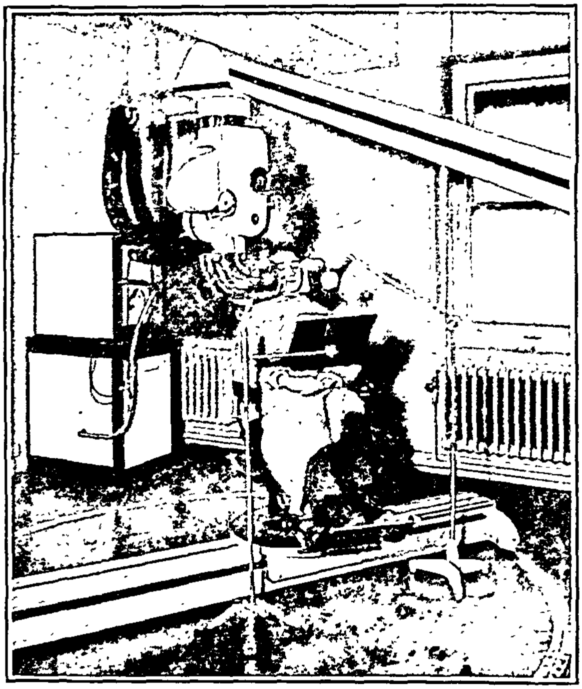


FIG. 120.—THE 4-GRAMME RADIUM BOMB IN USE. (MIDDLESEX HOSPITAL.)

The Choice of Radium or Radon as a Therapeutic Agent.—Since the supply of radon from a given supply of radium salt is practically inexhaustible, it follows that the gas, when separated from the parent radium, has but slight intrinsic value, so that no financial loss is to be apprehended from possible loss of the tubes. Moreover, the radium which is the source of the radon used will be kept in a safe place.

The disadvantages attending the employment of radon are:

(*a*) A large amount of radium is necessary for its preparation, and this can be used for no other purpose.

(*b*) A highly trained and skilled staff is required for carrying out the procedures necessary for its purification and separation.

(*c*) Radon disintegrates so rapidly that it is unsuitable for prolonged surface application.

The unit of radium emanation is known as the *Curie*, and denotes that amount of radon which is in radio-active equilibrium with 1 gramme of radium. For most practical purposes the *Curie* is too large a unit, and its thousandth part, the *millicurie*, is used instead. One gramme

of radium element in solution, *i.e.* as one of its soluble salts, will give 150 millicuries of radon capable of utilization for therapeutic purposes in twenty-four hours.

The Choice of Surgery or Radium as a Therapeutic Agent is still a matter which has not been settled satisfactorily. At the present time the position is somewhat changed, and the question in the treatment of neoplasms is rather what combination of surgery and radium therapy is likely to be the most efficacious. Two advantages may be fairly classified for radium surgery:

(1) The limitation of extent of the operation.

(2) Generally speaking, the introduction of radium is devoid of any operative mortality.

The insertion of radium needles has now become a recognized piece of surgical technique, wherein the objects aimed at are, firstly, a uniform irradiation of the neoplasm itself; and, secondly, a uniform control of possible areas of lymphatic dissemination. Remarkable results have been attained by this means, but it is a fatal error to regard radium as a panacea for malignant disease in all its forms, and as ousting operative procedure as the method of choice in all cases.

The actual results of radium treatment cannot be discussed *in extenso* in this book, but one or two facts and general principles may not be out of place.

(*a*) **Superficial Lesions.**—Many forms of superficial growths, both innocent and malignant, are effectively and satisfactorily treated by radium.

Cavernous nævi are made to disappear by surface applications of radium, with the advantage over surgery that no scar remains and a good cosmetic result is obtained. Keloids can be made to disappear by a similar treatment. The surgical treatment of keloids is unsatisfactory, as they invariably recur after operation.

Rodent ulcers usually respond to radium treatment with one application. It is, however, necessary to caution the patient—even when the lesion is apparently cured—to return for inspection. If a rodent ulcer does not respond well to radium, it is generally desirable to resort to surgery, as continual irradiation of an intractable rodent ulcer may lead to the development of a typical squamous-cell carcinoma.

Both radium and X-rays have been employed in the treatment of lupus, but the results obtained are inferior to those treated by means of ultra-violet light. However, in those cases which do not respond to light treatment, good results may be obtained by a surface application of radium. It is also true that a squamous-cell carcinoma has followed repeated applications of radium for lupus.

(*b*) **Carcinoma of the Breast.**—The treatment of carcinoma of the breast by radium is now a recognized procedure. Previously its use was confined to those cases which are inoperable, and large fungating growths were made to disappear. Recently, operable cases have been treated, but as the method is still under trial, it is not yet regarded as a substitute for operation.

The principle underlying the treatment of carcinoma of the breast is to cause the disappearance of all the malignant cells by delivering a lethal dose of radiation to—

(1) The whole of the affected breast;
(2) The axillary lymphatic glands;
(3) The supra- and infra-clavicular lymphatics; and
(4) The parasternal lymphatic glands.

In order that the dose may be adequate, the field of irradiation in the breast substance and the associated lymphatic areas must be as homogeneous as possible. This is best achieved by means of the insertion of radium needles. The needles used contain 2 or 3 milligrammes of radium, and are inserted parallel to one another at intervals of 1·5 cm., deep to the growth and on the pectoral fascia. Sometimes in a large breast an additional row of needles has to be inserted in a superficial plane. Needles of suitable length are inserted into (1) the axilla, (2) beneath the pectoralis major, (3) the infraclavicular region, (4) into the supraclavicular area beneath the deep cervical fascia, and (5) obliquely into the first four intercostal spaces.

The quantity used depends on the size of the breast, and in the case of a large breast as much as 100 mgm. of radium may be used. The needles are left in position for seven days. The full effect of this treatment is not seen for six weeks. A surface application of radium or a course of deep X-ray therapy is then given to the breast and lymphatic areas. This irradiation aims at the sterilization of the cells which have not been affected by the needling, and to provide for the irradiation of the mediastinum and pleura.

(*c*) **Carcinoma of the Buccal Cavity.**—In cases of mouth cancer, the treatment of the primary growth has been revolutionized during the last few years by the introduction of 'bomb' therapy. In these cases the results obtained by surgery alone were very poor. At the present time radium is undoubtedly the method of choice in treating most growths in the buccal cavity. By its use the primary growth can be made to disappear permanently.

The treatment of carcinoma of the mouth is conveniently divided into two stages. The first is the treatment of the primary lesions, and the second includes treatment of the glandular areas of the neck. The lesion in the mouth is treated first and the glandular areas are dealt with six weeks later.

In treating the primary lesion, teleradium is the method of choice, but interstitial radiation in the form of radium needles or radon seeds may be employed when the former is not available. For the anterior two-thirds of the tongue needles are customarily employed, because it is possible to obtain a more even distribution of the rays; but in the posterior third of the organ, the tonsil, or the pharynx, seeds are preferable, because they are easier to insert in positions which are not always readily accessible and because they tend to remain *in situ* better than the needles, when the latter are not tied in place (Figs. 121 and 122).

The treatment of the regional glands may be considered under three headings, depending on the clinical stage of the disease:

(*a*) When the glands are not palpable, surface irradiation alone is all that is needed.

(*b*) When the glands are palpable but not fixed, the method of choice is a block dissection of the neck followed by surface irradiation.

(*c*) When the glands are palpable and fixed, surgery is no longer possible and surface irradiation is all that can be given.

When the affected glands are circumscribed in area, 'bomb' therapy is the method of choice to employ. In other cases deep X-ray therapy should be given. When neither of these measures is available, a radium collar may be tried, a dosage of at least 10,000 milligramme hours being given at a distance of 1 centimetre.

(*d*) **Carcinoma of the Rectum.**—Carcinoma of the rectum has been treated by combined radium and surgery. In this case, however, the preliminary operation of access is definitely severe.

The results obtained to date are far from good. The best response is obtained in hypertrophic growths situated in the lower portion of the rectum.

In these there is retrogression of the growth and a decrease in the

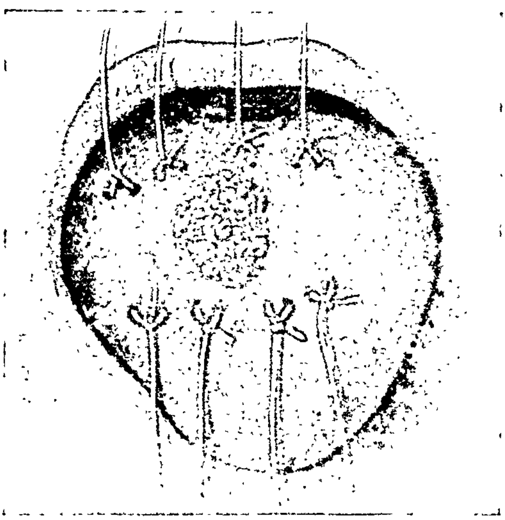


FIG. 121.—HYPERTROPHIC CARCINOMA, SHOWING NEEDLES SUTURED IN POSITION.
(From Ward's 'Recent Advances in Radium.')

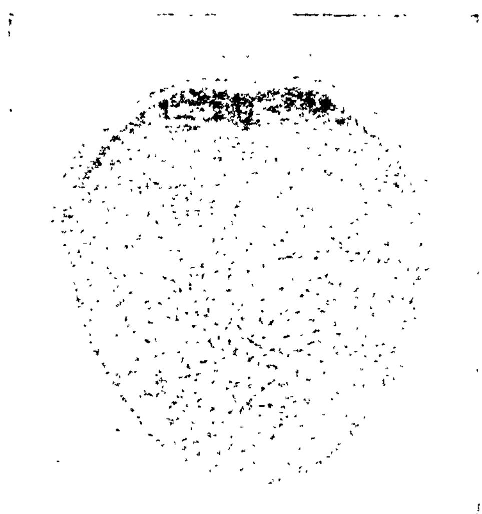


FIG. 122.—SAME CASE THREE MONTHS LATER.
(From Ward's 'Recent Advances in Radium.')

bleeding and discharge from the rectum. Preliminary colostomy is also necessary in order to avoid sepsis as far as possible, since septic changes militate against successful radium treatment.

Carcinoma of the **Anal Canal** in common with other squamous epitheliomata is radio-sensitive. Interstitial radiation gives good results, and if treatment is undertaken before the glands are involved the prognosis is good.

(*e*) **Carcinoma of the Bladder.**—Most malignant growths of the bladder are radio-sensitive. If the growth is operable, it should be excised and the operation area irradiated, either by means of radon seeds at the time of operation or by deep X-ray therapy later. If inoperable, the growth may be treated by means of low voltage therapy or radon seeds through a suprapubic opening, or else by means of deep X-ray therapy. The prognosis for this type of case, however, is not good.

CHAPTER XII.

INJURIES AND DISEASES OF ARTERIES—ANEURISM—LIGATURE OF ARTERIES.

Injuries of Arteries.

Contusion of an artery is the result of violence applied directly to the vessel wall. If atheroma or calcification exists, thrombosis often follows slight injuries, and dry or senile gangrene may ensue; but in healthy arteries a good deal of violence is needed to produce such an effect, as their natural elasticity enables them to yield or slip aside, and thus the consequences are usually insignificant.

Rupture or **Laceration** may also follow blows or strains, or may result from fractures or dislocations, or from attempts to reduce old-standing dislocations, or to break down intra-articular adhesions. If the rupture is **partial,** the inner and middle coats are usually torn, and this may be followed by thrombosis and occlusion. Where the lesion is limited to one side of the vessel, the clot may become organized over that spot, narrowing the lumen, but leaving an area of weakness from which an aneurism may subsequently develop. A dissecting aneurism (p. 325) may also result from such an accident. When complicated with a suppurating wound, an infective periarteritis may ensue, giving rise later on to secondary hæmorrhage.

Complete Rupture of an artery in a severe lacerated wound, such as is produced when a limb is torn off, often leads to but little hæmorrhage; the inner and middle coats give way at a higher level than the adventitia, and curl up within it, whilst the outer coat and sheath contract over them, and form an effective barrier. If, however, the artery is ruptured in a subcutaneous injury, such as a fracture or dislocation, extensive interstitial extravasation often ensues. A similar condition may ensue from a punctured wound of a vessel, where the track leading to it is valvular or becomes closed by clot or some external application.

The blood escapes into the tissues which are pushed aside and displaced, so that in time a cavity is formed, filled with fluid blood or soft clot, and surrounded by the tissues of the part, which after a time become matted together to form a fibrous wall lined by a deposit of fibrin of varying thickness. The size and shape of the cavity are determined by the resistance of the surrounding structures; thus in the upper part of the axilla the clavicle, costo-coracoid membrane, and pectoralis minor prevent extension forwards, and the tumour occasioned by the extravasation presents itself in the axilla or above the clavicle. As a rule the swelling develops rapidly, but sometimes hæmorrhage is prevented by temporary blocking of the opening in

the artery, and may only be lighted up later by injudicious movements or violence.

Symptoms.—The patient usually complains of feeling a snap, as though something had given way, accompanied by a sudden pain, localized to the injured part and often shooting down the limb in the line of the vessel. These are succeeded by the following phenomena: (*a*) *Locally*, a diffuse rapidly increasing swelling forms, which may be well described as a *Pulsating Hæmatoma*; this is tense and firm to the touch, and as the amount of fibrin increases may feel distinctly hard. It is not as a rule reducible, and indeed manipulation to determine this point is injudicious, as it may dislodge a portion of clot. Distinct pulsation of an expansile type is usually present, and often a systolic bruit and some degree of thrill, but these may not develop if the cavity is very tense, or if much fibrin is present, or if the wounded artery is very deep. The skin is stretched, but remains unchanged unless the swelling is approaching the surface. (*b*) *Distally*, the signs depend on the amount of interference with the circulation and with surrounding structures, especially the nerves. If the artery is torn completely across, the pulse in the vessels below ceases, and œdema may result from pressure of the blood-clot on the veins; if the artery is only partially divided, some amount of circulation distally may persist. Pressure on the nerves at first causes numbness, tingling and neuralgic pain, but later on may determine loss of power or complete anæsthesia. It must not be forgotten, however, that some of the nerves adjacent to the injured vessel may have been wounded simultaneously with the artery. (*c*) *Generally*, the signs of hæmorrhage and shock manifest themselves in varying degree, according to the amount of blood lost and the character of the violence.

Results.—(1) The swelling may increase steadily in size until the skin becomes so distended as to *rupture* or slough, and then, if help is not at hand, the patient dies of hæmorrhage. Occasionally the bleeding continues into an internal cavity, or into the tissues of a limb, to such an extent as to cause death without any external loss of blood. (2) *Suppuration*, accompanied by the general signs of fever, may result from auto-infection, or from the entrance of bacteria through the small valve-like wound. The whole swelling becomes red, hot, œdematous, and excessively tender, looking like a large abscess. Rupture and external hæmorrhage will probably conclude the case if surgical assistance cannot be obtained. (3) The pressure of the extravasated blood upon the veins or on the arteries needed for the collateral circulation may determine *gangrene* of the extremity, which is almost always of the moist type. (4) The process may become more or less *limited* after a time by coagulation occurring in the divided mouth of the vessel, which is thus occluded. Collateral circulation may be established, and thereby the health and vitality of the limb are maintained, whilst the blood-clot is absorbed or organized.

Treatment.—Whenever practicable, the part should be laid open, the clots turned out, and the injury to the arterial wall repaired. To undertake this, temporary hæmostasis must be secured by the use of a tourniquet in a limb, or by digital compression, or by applying

a temporary ligature or a Crile's clamp to the trunk above. In some cases, *e.g.* a torn artery in the buttock, none of these plans are feasible, and then it may only be possible to make an opening in the sac just large enough to introduce a finger, and with this the actual bleeding-point must be sought and controlled, and then the wound can be laid freely open and the vessel secured. In some cases it will be necessary to release the tourniquet or clamp for a moment or two in order to find the upper end, but as a rule this is not a difficult task. The lower end is often more difficult to find, though if it can be exposed at a lower level it may be possible to trace it up; if, however, this is unsuccessful, owing to the infiltrated condition of the parts, then the cavity, after being emptied of clot, is well packed with gauze, and a tourniquet kept on the limb for immediate use, if need be. It is most important to ligate or deal with the actual wounded end of the vessel; proximal ligature may be quite ineffective, owing to the existence of a branch between the ligature and the wound.

A **Penetrating Wound** of an artery, if completely dividing the vessel, is always followed by hæmorrhage, although the blood may be unable to escape externally. If a large artery is cut cleanly across, the bleeding is copious, whilst from a small vessel it soon ceases, owing to the contraction and retraction of the coats.

When an artery is 'button-holed,' *i.e.* when a small segment of the wall is cut through, the hæmorrhage is often continuous and prolonged, since retraction opens up the wound, and contraction is thereby hindered. The treatment of this condition consists in completing the division of the injured trunk if it is a small one, but if it is of large size, it must be dealt with according to the rules given below for punctured arteries.

A clean incised wound of an artery varies in its results somewhat according to its direction; thus if it is in the long axis of the vessel, it gapes but little, and the loss of blood may be but slight, whilst if transverse or oblique, both contraction and retraction tend to increase the size of the opening, rendering it more nearly circular, increasing thereby the hæmorrhage.

A punctured wound of an artery varies in its results with the size and character of the penetrating body. Thus a vessel may be traversed by a needle without hæmorrhage, or subsequent ill-effect, but a larger puncture, as by the blade of a knife or stiletto, results in extravasation. If it ceases after a time, the blood-clot is absorbed and the wound in the vessel closed by a cicatrix, which may subsequently yield and give rise to a circumscribed aneurism. This is not unfrequent in the neighbourhood of the wrist from glass wounds, involving the radial or ulnar trunks, and hence is usually seen in window-cleaners or mineral-water bottlers.

Treatment.—So much progress has been made of recent years in connection with the surgery of arteries that it is now accurate to say that the ideal treatment of all penetrating lesions of arterial walls is the repair of the lesion and restoration of the lumen of the vessel; of course, this dictum applies only when the arterial tunics are healthy; when they are in a pathological condition repair is rarely possible,

and then all that can be done is to apply ligatures above and below the wound in the vessel, as also to any branch that may arise between the ligatures. Simple linear wounds or slits in the arterial wall may certainly be sutured with every prospect of success if certain precautions are taken. The circulation must first be controlled, and the most stringent precautions taken as to asepsis. The hæmatoma is opened up by a suitable incision, and all the blood-clot turned out so as to expose the wound in the vessel. The lesion is carefully but thoroughly explored to ascertain whether it involves only one or both sides of the vessel, and then sutures are introduced passing through all the coats of the artery down to, but not through, the intima. Fine silk is employed, previously sterilized in vaseline or in liquid paraffin at 105° C.; the needle should be round-bodied, of the smallest size, and straight or curved, as may be thought best. If the wound in the vessel is irregular, and yet appears to be capable of *lateral suture*, the irregular margins should be carefully trimmed, clots removed, and the parts lightly rubbed over with sterile paraffin; the lumen of the artery may be slightly encroached on, but that is better than ligation of the vessel, or an end-to-end anastomosis.

For irregular tears of an artery or when the whole calibre has been involved, and possibly some retraction has taken place, ligature is often the only practicable method of treatment, but in experienced hands and when the conditions are favourable, it may be possible to excise the injured area, to free the vessel above and below, guarding carefully all branches, and then to restore the vessel by an *end-to-end anastomosis*.

Arterio-Venous Wounds follow penetrating injuries which involve an artery and vein lying in close contact, *e.g.* at the bend of the elbow between the median basilic vein and the brachial artery, in the neck between the internal jugular and carotid, in the leg between the femoral vessels, and occasionally in the orbit. They are also not unfrequently met with in military surgery, as a result of the penetration of tiny shell or bomb fragments, or even of a bullet which does but little harm to the soft tissues. Small vessels may be involved as well as the main trunks, *e.g.* (to mention a few actual cases) the facial artery and the temporo-facial vein, the transverse cervical artery and vein, one of the smaller arteries of the groin and the upper end of the internal saphena vein, etc. Two conditions may result.

An **Aneurismal Varix** is produced by a direct communication between an artery and a vein, no dilated passage intervening between the vessels (Fig. 123, A). The venous walls, unfitted to withstand arterial pressure, are thereby dilated and rendered varicose. A pulsating venous tumour results, the dilatation extending for a variable distance above and below the opening, and at each beat of the heart a loud whizzing sound can be heard, likened by some authors to that caused by an imprisoned bluebottle fly buzzing in a thin paper bag. On palpation the thrill of the blood as it enters the vein can often be detected.

Treatment.—Nothing is usually required beyond the application of an elastic bandage or support to prevent further enlargement. Should

pain or inconvenience arise in spite of this, it may be possible to repair the wound in the arterial wall by suture, or, failing that, the artery must be secured above and below the abnormal communication with the vein. Generally the latter is so distended that it has to be removed before the artery can be reached, but the simultaneous occlusion of artery and vein is not a very serious matter in these cases.

A **Varicose Aneurism** differs from the above in that an aneurismal sac exists between the artery and the dilated vein (Fig. 123, B). It is produced when the vessels are placed at a short distance from each other, or when extravasation of blood has separated them. The aneurism is of the false type, its walls being composed of newly-formed cicatricial tissue; it is almost certain to become diffuse. The physical signs are similar to those of aneurismal varix, except that the aneurism can sometimes be detected by palpation, whilst a soft bruit may be heard over it.

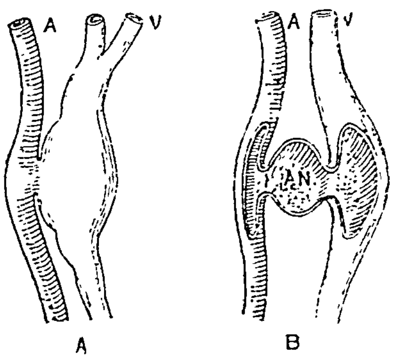


FIG. 123.—DIAGRAM OF A, ANEURISMAL VARIX; AND B, VARICOSE ANEURISM.

A, Artery; V, vein; AN, aneurism

Surgical **Treatment** is always required in these cases. An attempt should be made to repair the damage to the walls of the artery and vein, either by lateral suture or by end-to-end anastomosis. Not unfrequently this type of treatment is impracticable, and then the damaged sections of the vessels together with the aneurism may be excised with good results, since the lesion usually occurs in healthy adults. It may suffice, however, to tie the artery immediately above and below the wound.

Inflammation and Degeneration of Arteries.

1. **Traumatic Arteritis** is the result of injuries, such as total or partial division of the vessel, laceration, bruising, etc. The phenomena are merely those of repair, resulting in closure of the wound or occlusion of the vessel; they have been already described.

2. **Infective Arteritis** results from bacterial invasion of the arterial wall, and that usually from without (*periarteritis*) and in connection with infected wounds and ligatures, or spreading ulceration. It is characterized by hyperæmia and softening of the vascular tunics, the fibres of which lose their cohesion with each other, owing to the peptonizing action of the toxins. In the smaller arteries thrombosis usually occurs and seals the vessel; but in the larger there is considerable danger of bleeding. Secondary hæmorrhage from arteries tied in their continuity is generally due to this cause, as also bleeding from phthisical cavities, the vessels having previously lost the support of surrounding tissues, and being more or less dilated or aneurismal.

3. **Embolic Arteritis.**—When a vessel is blocked by a simple embolus, obliteration is the usual consequence. If the embolus is infective,

as in pyæmia or infective endocarditis, an abscess may develop; but if the irritant is less intense, the process may stop short of suppuration, and yet an aneurismal dilatation of the softened wall takes place. The latter process is the most common cause of *spontaneous* aneurism in children and young adults.

4. **Acute Endarteritis** is usually seen in the aorta associated with acute endocarditis, or sometimes in the smaller vessels near inflamed wounds. It is evidenced by the presence on the inner aspect of the vessel of more or less raised patches, somewhat pinkish and gelatinous in appearance, soft and elastic in consistency.

5. **Arterio-sclerosis** is the term now applied to a degenerative and inflammatory affection of the arteries, formerly known as *chronic endarteritis*. It usually commences about middle life, and is in many cases merely a physiological sign of the incidence of senility due to the wear and tear of life. In younger patients and in its more severe forms it generally depends on some form of chronic intoxication, *e.g.* syphilis, gout, alcoholism, or lead-poisoning. It is also induced by excessive and particularly intermittent muscular strain; by cachexia, the result of malignant disease, tuberculosis, or inanition; it may follow as a sequela of acute infections, such as enteric fever or acute rheumatism; or may arise from any condition which leads to persistent increase in the arterial tension, *e.g.* chronic Bright's disease.

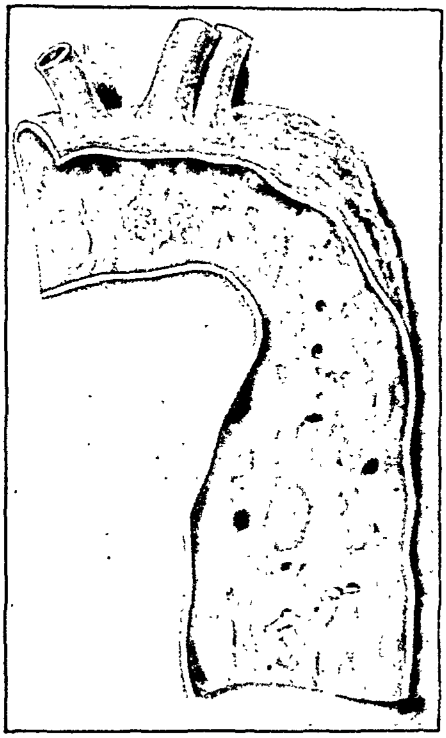


FIG. 124.—ATHEROMA OF AORTA.

The primary changes probably consist in a degenerative loss of elasticity in the middle and outer coats, which is followed by a secondary hyperplasia of the tunica intima. The later effects vary somewhat, according to whether the affection is localized (nodular variety) or diffuse.

Nodular Arterio-sclerosis or *atheroma* is most common in the aorta and large vessels, and often starts in the convexity of the aortic arch at the spot where the impact of the blood-stream is felt as it is ejected from the ventricles (Fig. 124), or in places where the vessel passes over or around some bony projection, or at the bifurcation of a main artery. In the early stages scattered raised patches are seen on the inner lining of the vessel, translucent and greyish in aspect, and of variable size; the overlying endothelium is smooth and intact. In the later stages fibrosis may occur in the patch, which becomes dull white in colour, and at length calcification may ensue, giving rise to an atheromatous plaque. In other cases the process may be followed

by fatty degeneration, the patches becoming yellowish in colour and irregular in outline; they are small at first, but increase in size, and coalesce one with another. The contents are now fluid or cheesy in consistency, the pultaceous material consisting of fatty granules and débris, with oil globules and plaques of cholesterine. It may be absorbed entirely, leaving a weakened spot in the wall of the vessel, from which an aneurism may arise; or it may be infiltrated with lime salts, and constitute an atheromatous plaque; or the tunica intima may give way over it, allowing the contents to be swept into the general circulation, where it probably does no harm. The outer coat has by this time

FIG. 125.—ARTERIOGRAM SHOWING ATHEROMA OF FEMORAL AND POPLITEAL ARTERIES. (MR. A. M. BOYD'S CASE.)

become thickened, and hence no immediate ill result follows the breach in the inner coats, although subsequently dilatation may take place. Again, the blood may find its way through the opening into the substance of the wall and strip up the inner from the outer layers, constituting a 'dissecting aneurism'; or a localized thrombus may form, causing occlusion of the vessel.

Diffuse Arterio-sclerosis occurs in elderly individuals, commonly in the smaller vessels, and may be associated with the nodular variety in the aorta. In the lower extremity this can often be demonstrated by the injection of thorotrast into the main vessels (Fig. 125). The changes are similar to those described above, but usually terminate in fibrosis and contraction of the lumen of the vessel; the changes in

the intima are followed by thickening of all the coats, but degenerative phenomena are unusual. In the smaller arteries of the brain this change may interfere seriously with the functions of the part; whilst in the vessels of the limbs it may result in what is known as *Endarteritis obliterans*, and lead to gangrene. In some instances even the main trunks may be involved in this affection.

6. **Chronic Syphilitic Endarteritis** is chiefly met with in the late secondary or tertiary stages, and is characterized by an overgrowth of the tunica intima (Fig. 126, *a*), which is subsequently associated with infiltration of the media (*c*), and much more so of the adventitia (*d*). The change occurs in small arteries, especially those of the brain or kidneys, or in the neighbourhood of gummata, and but rarely

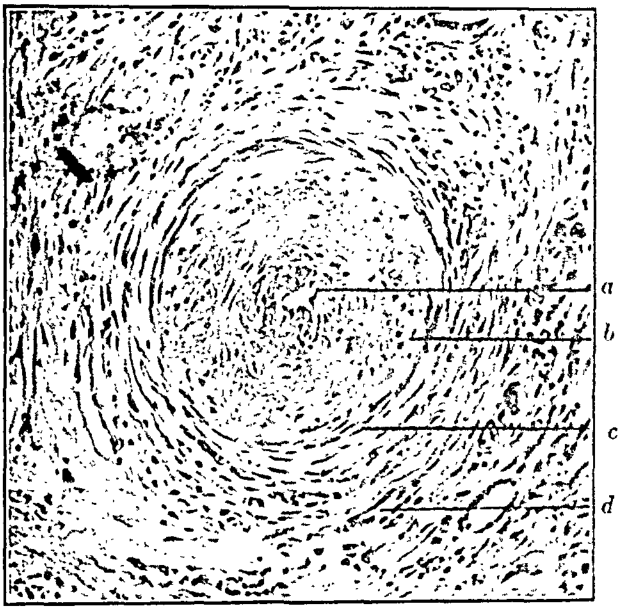


FIG. 126.—SYPHILITIC ENDARTERITIS FROM NEAR A GUMMA. (× 120.)

a, Intima greatly thickened by newly-formed fibro-cellular tissue; *b*, fenestrated elastic lamina of Henle; *c*, muscle fibres of media infiltrated towards the left; *d*, adventitia thickened by cell infiltration and hyperplasia.

in the larger vessels, although a considerable percentage of individuals affected with internal aneurism have suffered from syphilis. It differs from simple atheroma—(1) in attacking small arteries; (2) in affecting the whole circumference of the vessel, and not merely patches; (3) the newly-formed tissue becomes vascular, and does not undergo fatty degeneration; and (4) it leads to narrowing or occlusion of the vessel rather than to weakening and dilatation. When involving the cerebral arteries, various forms of monoplegia, or even hemiplegia, may result.

7. **Chronic Tuberculous Endarteritis** of a similar type is met with in all places where tubercle is actively developing; in fact, tubercles are often formed around arterioles, and lead to their obliteration. The tuberculous endarteritis may, however, spread widely beyond the

focus of the mischief, and in almost any portion of pulpy granulation tissue this change can be seen.

8. **Primary Calcareous Degeneration** (Fig. 127) is chiefly met with in the smaller arteries of the extremities. It occurs in elderly people at the same time of life as the calcification of cartilages, etc., and commences by the deposit of lime salts in the muscular fibres of the tunica media, constituting a series of calcareous rings which transform the elastic expansile vessels into rigid tubes like gas-pipes, through which

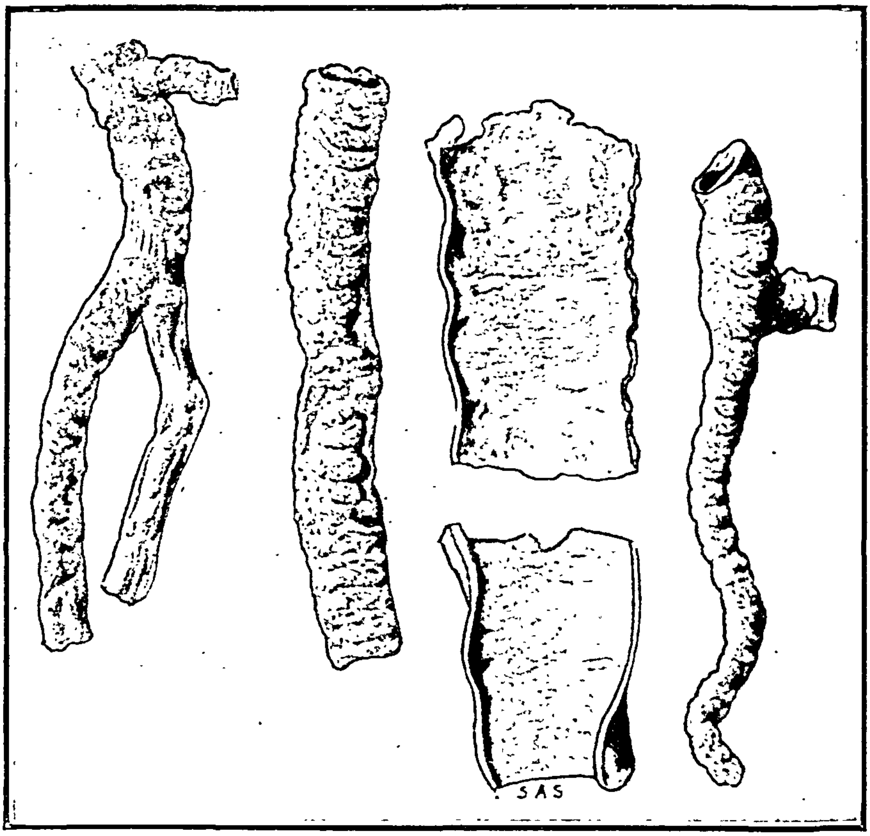


FIG. 127.—PRIMARY CALCAREOUS DEGENERATION OF ARTERIES.

can pass only a fixed minimal supply of blood. It is often associated with generalized arterio-sclerosis. The condition is often revealed by radiography.

The affected limb passes into a condition of chronic anæmia and impaired nutrition, resulting in coldness of the feet or hands, cramps and spasms of muscles, sensations of pins and needles, etc. The endothelium is not removed except in the later stages, and then thrombosis may be produced, or a similar result may arise from the lodgment of an embolus. Senile gangrene (p. 92) is a common termination.

9. **Amyloid Degeneration** of the viscera commences in the arterial walls, but is described elsewhere (p. 56).

The Effects of Arterial Inflammation and Degeneration are both local and peripheral. *Locally,* **Thrombosis** may be produced whenever the lining endothelium is removed and a raw surface exposed, upon which fibrin can collect. Under this fibrinous coating repair is often effected without further complication; but if the blood-stream is retarded, or the lumen of the tube narrowed, complete thrombosis may follow, the clot extending some distance up or down the vessel, or even from a branch into the main trunk, which may be blocked by this means. **Aneurism** is also a result of any weakening of the arterial tunics. **Obliteration** of the artery is caused either by thrombosis, or by excessive proliferation of the tunica intima (as in syphilitic or tuberculous disease), or by gradually increasing pressure from without. Lastly, **Spontaneous Rupture** is occasionally produced.

Peripherally, defective blood-supply and consequent **lowered vitality** are the most marked results of arterial disease, leading to various forms of ulceration and gangrene. Thus, senile gangrene is due to calcareous changes in the arteries, fatty degeneration of the heart follows atheroma of the coronary arteries, whilst softening of the brain may ensue from various affections of the cerebral vessels. Similar results may also arise from **emboli** detached from areas of local disease.

Aneurism.

An **Aneurism** is a sac filled with fluid or coagulated blood communicating with the interior of an artery, the walls of which have become dilated.

Causes.—1. **Changes in the Vessel Walls,** by which their resistance to the intravascular pressure is diminished. Many varieties of *disease, e.g.* atheroma, predispose to aneurismal dilatation, especially if occurring in syphilitic or gouty men about middle life, in whom, although the arterial tunics may be weakened, the power of the heart and the resulting blood-pressure are by no means diminished. The diffuse form of arterio-sclerosis (often associated with calcification) of the peripheral arteries is antagonistic to aneurismal dilatation. Any *injury,* a contusion, a penetrating wound, or a strain, may so interfere with the integrity of the vascular coats as to result in aneurism, and, indeed, a cicatrix in an arterial wall must always be looked on as a weak spot predisposing to dilatation. The lodgment of an infected *embolus* in the smaller arteries is stated to be one of the most common causes of spontaneous aneurism in young people.

2. **Increase in the Blood-Pressure** is another factor, especially when due to heavy *strain* or *exertion,* which leads to irregular excitement and increased action of the heart. Steady laborious employment, such as is seen amongst artisans and mechanics, or regular exercise, does not appear to predispose to this condition; but irregular intermittent efforts, in which for the time being every power is strained to its utmost, are very liable to determine its occurrence. A day's exertion in the hunting or shooting field, or strenuous golf, by an elderly man, accustomed to sedentary occupations, is often the cause of some vascular lesion, such as aneurism, apoplexy, etc. Hence aneurisms are more frequently seen amongst men than in women,

in the proportion of seven to one; whilst they are much more common among the dwellers in Northern climates than in the more lethargic and ease-loving inhabitants of the South.

Structure of an Aneurism.—The *sac* consists more or less evidently of a distension of all or part of the original walls of the vessel whilst it is small; but as the aneurism increases, the original structure is replaced by a mass of newly-formed fibrous tissue, due to a condensation and matting together of the surrounding structures, with or without an internal lining of laminated fibrin deposited on parts where the endothelium has disappeared. The *contents* of the sac depend on the character, age, and size of the aneurism. Whilst still small and with a complete endothelial lining, it contains fluid blood; but as the tumour grows, and especially if of the sacculated type, fibrin is deposited in layers which gradually encroach on the cavity, and may in time completely fill it, so that in rare cases a spontaneous cure results. The oldest laminæ are dry and yellowish-white in colour; those more recently deposited are softer and more reddish, whilst the last formed is merely like ordinary blood coagulum. No single lamina covers the whole area, but layer is arranged over layer (Fig. 128) in such a manner that the oldest and necessarily the smallest laminæ are nearest to the sac wall.

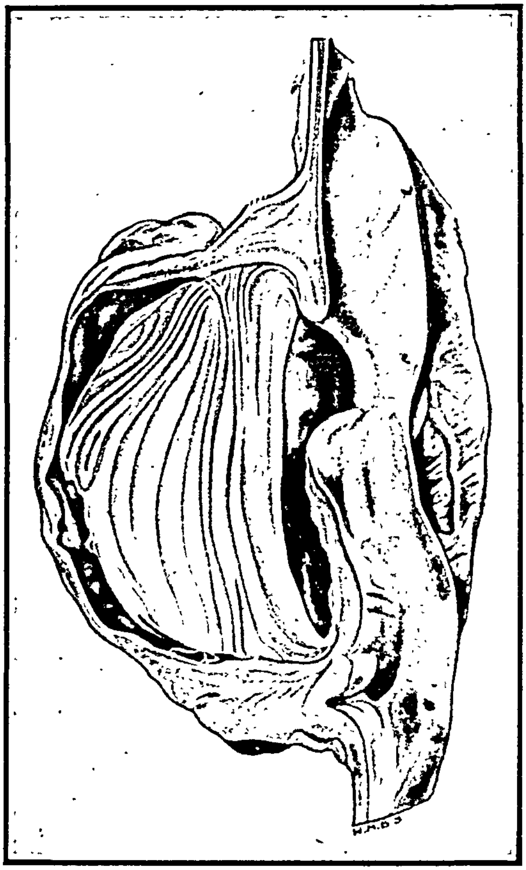


FIG. 128.—SACCULATED ANEURISM. (ROYAL COLLEGE OF SURGEONS MUSEUM.)

The small mouth of the saccule is clearly seen, and the cavity is nearly filled with laminated clot.

Three chief **forms** of aneurism have been described: the fusiform, sacculated, and dissecting.

1. The **Fusiform Aneurism** (Fig. 130, A) is one in which the whole lumen of the vessel is more or less equally expanded, so that the swelling is tubular in character. It is generally due to a widely-extended disease of the arterial walls, and hence is more common in the larger internal vessels, such as the aorta, than in those of the extremities. The tunica intima is usually represented throughout the whole extent of the sac, but is thickened and atheromatous in patches, the margins and surfaces of calcareous plates being indicated by

flocculi of fibrin, which are attached to them, although no regular laminated deposit may be present. The tunica media is stretched, atrophied, and in the later stages practically non-existent, whilst the adventitia is much thickened by inflammatory new formation and by incorporation with the surrounding tissues. The progress of fusiform aneurisms is generally slow, so that in some situations, *e.g.* the thorax, they may attain enormous dimensions, and cause grave pressure symptoms. A natural cure is almost impossible, and hence, if unchecked by treatment, rupture of the sac is likely to occur, especially if, as often happens, one portion of the wall yields more rapidly than another, thereby inducing a localized sacculation.

2. A **Sacculated Aneurism** (Figs. 128, 129, and 130, B) is due to the yielding of some weak patch in the vessel wall which does not involve the whole circumference, or, as just mentioned, it may spring from a fusiform aneurism. It communicates with the interior of the artery by an opening of variable size. All traumatic aneurisms, whether due to the yielding of a cicatrix, or to the partial division of the coats of the vessel, are of this type, which is hence found most commonly in the extremities (Fig. 129). The inner and middle coats can usually be traced as far as the mouth of the saccule, but there they are suddenly lost, the wall being constituted by a mass of fibro-cicatricial tissue, upon which laminated fibrin readily forms, thus increasing its thickness and power of resistance. Their progress is, however, much more rapid than that of the fusiform, generally ending in rupture or diffusion, although occasionally a natural cure results.

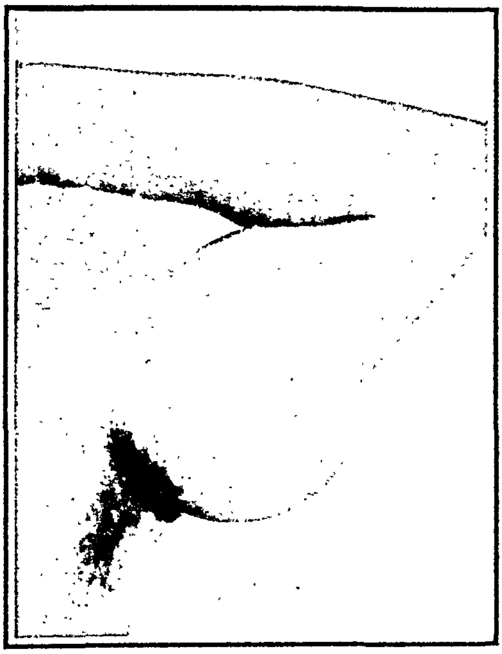


FIG. 129.—ANEURISM OF THE UPPER PART OF THE BRACHIAL ARTERY DUE TO OLD INJURY.

3. A **Dissecting Aneurism** (Fig. 130, C) is one in which the blood forms a cavity within the wall of the vessel by stripping up the inner from the outer half, the line of cleavage being within the middle coat, half going with the adventitia, half with the intima. It is usually the result of extensively diffused atheroma. The blood thus driven into a cul-de-sac may remain limited to this cavity for some time, or it may find its way outwards and become diffused, or burst back through another atheromatous spot in the interior of the vessel. The condition occurs chiefly in the thoracic or abdominal aorta, but cannot be recognized *ante mortem*.

Symptoms and Signs of a Circumscribed Aneurism.—These may be divided into two groups: the intrinsic and extrinsic.

Intrinsic Signs.—A tumour, pulsating synchronously with the heart's beat, is present in the course of a vessel. The pulsations are distensile or expansile in character, *i.e.* the whole tumour increases in size at each systole, and that evenly in all directions, so that if the tumour is lightly grasped in any position the fingers are separated. A definite thrill can often be felt as the blood enters the sac at each heart-beat. If the supplying vessel is compressed on the proximal side, the pulsation ceases, and the tumour diminishes in size and becomes softer; this is more marked in fusiform than in sacculated aneurisms. The application of pressure to the sac itself, whilst the afferent trunk is compressed above, may still further diminish its size. On removing

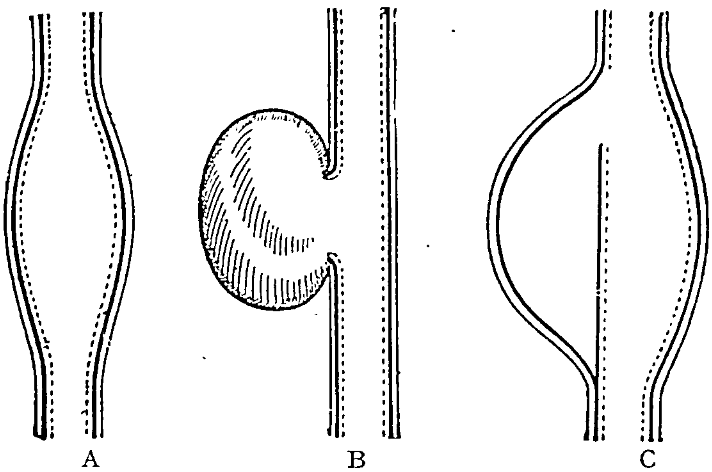


FIG. 130.—DIAGRAMS OF FUSIFORM, SACCULATED, AND DISSECTING ANEURISMS

In the fusiform (A) the walls are expanded, but more or less normal in texture; in the sacculated (B) the normal structure of the arterial wall ceases abruptly at the commencement of the saccule; in the dissecting (C) the arterial wall is split into two lamellæ.

The interrupted fine line is supposed to represent the intima; the continuous dark line, the media; and the continuous fine line, the adventitia.

the pressure, the swelling regains its old dimensions in a certain definite number of beats, usually not more than two or three. Pressure on the distal side of the sac makes it more tense and the pulsation more marked, unless such compression is very prolonged. On auscultating the tumour, a bruit of variable character may be heard; usually it is loud, harsh, and systolic, but sometimes quiet and musical.

The **Extrinsic Signs** of aneurism are those occurring in neighbouring or distal structures from its constantly increasing size and **pressure**, and the interference produced by it with the circulation. The *pulse* on the distal side is diminished and delayed, its diminution being caused partly by the obstruction experienced, but also in some cases by the pressure of the sac upon the trunk above or below the tumour. The delay is due to the interference with the transmission of the heart's impulse by the intervention of the aneurismal sac. The smaller

vessels engaged in establishing collateral circulation may be compressed by the sac, and thus the vitality of the limb impaired. Pressure on the accompanying vein or *veins* results in diminution of their calibre, and possibly a localized thrombosis, together with distal congestion and œdema. Compression of *nerves* occasions neuralgia, spasm, or paralysis. *Muscles* are displaced, expanded, and attenuated; *bones* may be eroded, as evidenced by a deep, constant, boring pain, and even spontaneous fracture may ensue; whilst *joints* are encroached upon and disorganized. *Tubes*, such as the trachea or œsophagus, are often constricted and even laid open by ulceration. It is interesting to note that resisting tissues, like bone, are much more liable to be eroded than elastic, yielding structures, such as cartilage; where the vertebral column is encroached upon by an aneurism, the bones are always destroyed more than the intervertebral discs.

A certain amount of compensatory hypertrophy of the *heart* is often present. Fibrinous masses are occasionally set free as *emboli*, and lead either to a spontaneous cure, or to gangrene of the parts supplied by the vessel, or to death if the brain is involved. *Gangrene* may also result from the diminished blood-supply to peripheral parts; it is usually of the dry type, involving merely one or two fingers or toes, unless the veins are compressed, when it may be of the moist variety.

The **Differential Diagnosis** of a circumscribed aneurism is usually not difficult, but the following conditions may simulate it somewhat closely: 1. A *tumour* or *chronic abscess* situated near an artery, and deriving *transmitted pulsation* from it, is recognized by the impulse being merely heaving in character, and not expansile; by the pulsation ceasing entirely if the tumour is lifted from the vessel, or allowed to fall away from it by assuming a suitable position; by the size of the tumour not diminishing if the pulsation is stopped by pressure on the vessel above; and by the fact that after stoppage of the pulsation the first beat is equal to the subsequent ones, whereas in an aneurism it almost always requires more than one beat to re-establish the strength and force of the impulse. Moreover, the pulse below is not affected in the same way or to the same extent as when an aneurism is present. 2. An *artery* is sometimes *pushed forwards* by an underlying growth, and its pulsation in a more than usually superficial position may suggest an aneurism. The distinguishing features are the limitation of the pulsation to the line of the vessel, and the absence of pulsation in the underlying growth. 3. A *pulsating sarcoma* or *nævus* is known by being rarely limited exactly to the line of the artery, pulsation being present in situations where an aneurismal dilatation could not be felt, and being less forcible and regular in its character. The consistency of the swelling is more variable, and pressure over the afferent trunk does not diminish its size to any marked extent. Moreover, a sarcoma is usually more adherent to the deeper structures, and its limits are not so accurately defined. 4. The pain caused by an aneurism may cause it to be mistaken for *rheumatism or neuralgia*, *e.g.* for sciatica in popliteal aneurism, and in every case of obstinate pain of this kind the arteries should be carefully examined.

Natural Terminations and Results.—1. **Spontaneous Cure,** though very unusual, may occur in sacculated aneurisms. (*a*) It may be due to the *gradual* deposit within the sac of fibrin, which, in the first place, limits the expansion and extension of the aneurism, but may finally increase to such an extent as to occupy the whole cavity and close up its mouth. This condition can only obtain in saccules with small mouths, and in vessels of the second magnitude, hardly ever in the aorta or larger trunks, the impetus of the blood-stream being too great to permit of the necessary deposit of fibrin. (*b*) It may arise as the result of the *sudden* coagulation of all the blood in the sac from the stoppage of the circulation, owing to the lodgment of an embolus either at the mouth of the aneurism or in the trunk immediately below. (*c*) The aneurism may become so large as to compress the main vessel, either going to or coming from it, thus bringing about its own cure. (*d*) Again, if the sac becomes inflamed, consolidation may occur with or without suppuration, although the latter process, as will be seen anon, is attended with serious danger to life and limb.

The sac becomes more and more firm, the pulsation less forcible and distinct, the bruit diminishes, and finally consolidation is effected, a firm fibroid tumour alone remaining, which gradually shrinks, whilst the collateral circulation is opened up so as to supply the limb below. It is sometimes by no means easy to recognize the fibroid mass which results from a *consolidated aneurism,* and in making a diagnosis the history has mainly to be depended on. The existence of a tumour in the line of an artery, the probable occlusion of the main trunk, and the fact that the circulation is carried on by means of collateral branches, are the chief points which can be ascertained by a physical examination.

2. **Diffusion and Rupture** result from yielding of the walls of an aneurism, as an outcome of some mechanical injury or from simple over-distension.

When an **internal** aneurism gives way, the patient usually experiences a sensation of pain in the part, and becomes pale, cold, and faint, possibly dying within a few minutes or, at most, hours; or there may be a sudden gush of blood from the mouth if the trachea or œsophagus has been opened. Sometimes internal aneurisms leak slowly, and the final stage lasts some days.

When an **external** aneurism yields, it may do so slowly or quickly. If the blood becomes effused *slowly* (a *leaking* aneurism), the tumour gradually increases in size, and its outline is less clearly limited; the pulsation diminishes in force and distinctness, and the signs of pressure upon the veins or nerves become more urgent, until gangrene sometimes supervenes. If the sac yields *suddenly* (a *ruptured* aneurism), the patient experiences severe pain in the part, which becomes tense, swollen, and brawny; all pulsation ceases, both in the aneurism and below it, and gangrene of the limb follows, or even death from syncope, if the skin gives way. Suppuration may also occur in these cases.

3. **Suppuration** is an exceedingly serious, but by no means a usual, complication. It may arise in the following ways: (*a*) After ligature of the main vessel, especially when the wound becomes infected, and

there is a good deal of loose cellular tissue around the sac, as in the axilla; (*b*) after diffusion, partial or complete, of an aneurism, where there is great tension upon surrounding parts. Auto-infection or the presence of an infective embolus may finally determine the suppurative process. The tumour shows signs of inflammation, becoming hot, red, painful, and swollen, and the skin over it may pit on pressure; whilst fever and general constitutional disturbance are also present. Sooner or later, if left to itself, the tumour points at one spot and bursts, giving exit to a mixture of blood-clot, pus, and a greater or less amount of bright red blood. The patient either dies at once from syncope, or a little later from secondary hæmorrhage and toxæmia, unless efficient treatment is adopted.

Treatment.—I. **General** treatment is employed as an accessory to surgical measures, or must be relied on entirely in cases where local means are impracticable, as in internal aneurisms.

In *plethoric* individuals, where the disease often runs a rapid course, absolute rest, both mental and physical, must be enjoined, with the removal of all sources of irritation and worry. The bowels should be kept gently open, and constipation and straining avoided. The heart's impulse may be diminished by the use of drugs, or even by venesection when it is very forcible. Iodide of potassium is usually prescribed, on account of the frequent association of aneurism with syphilis; and calcium lactate (grs. v., t.d.s.) may be useful in increasing the coagulability of the blood. The diet must be suitably diminished, and only highly nutritious material allowed, and that mainly of the nitrogenous type, with as little fluid as possible (not more than about a pint a day).

In *weakly individuals*, whilst strictly enjoining a recumbent posture, the surgeon should prescribe iron and a somewhat more liberal diet, in order to improve the quality of the blood.

II. **Surgical Treatment.**—A. The ideal plan consists in dealing with the arterial walls so as to obliterate the aneurism, but without occluding the original lumen of the vessel, according to the suggestion of Matas of New Orleans. This is obviously only possible in selected cases of sacculated aneurism, but a number of satisfactory results have been reported. The circulation is controlled temporarily, and the aneurism laid freely open, so that its interior can be emptied completely and carefully examined. The orifices of the smaller collateral branches are secured by purse-string sutures, and the margins of the main opening are approximated by a row of Lembert's sutures, if need be, over a piece of rubber catheter, which is subsequently removed; the continuity of the original vessel being thus restored, the aneurismal walls are brought together by superimposed rows of Lembert's sutures. It is probable that in many instances the artery becomes obliterated in spite of the surgeon's care.

B. **Complete Extirpation** of the aneurismal sac, as if it were a tumour, may be looked on as the best method of treatment in the majority of cases. The limb is exsanguinated by elevation, and in suitable cases the aneurism is removed without opening it, and the vessel secured by ligature above and below, as also any branches which

may arise from it. Sometimes, however, it is necessary to open it and turn out its contents before attempting its extirpation, which is often a matter of considerable difficulty owing to the adhesions present. Not unfrequently the vein will be encroached on in this dissection, and it may have to be removed; bad results are not likely to follow, since the pressure of the sac has already probably established an efficient collateral venous circulation. The results of this operation are most satisfactory, since the length of treatment is curtailed, and all chances of local recurrence are removed. Gangrene also is uncommon, since only one set of collateral circulation is called upon, *viz.* that required to bridge the gap made by removing the aneurism, whereas in the Hunterian operation a double set is needed, *viz.* at the site of the ligature, and round the consolidated aneurism.

C. The **deposit within the sac of fibrin,** which shall subsequently organize and thus lead to the obliteration of both sac and supplying vessel, was the ideal aimed at by the earlier surgeons, and has still to be relied on in many cases. It is obvious that a slow and gradual deposit of laminated fibrin is likely to be more satisfactory than the sudden distension of the sac with soft red clot.

The various plans adopted with this end in view are as follows:

1. **Compression** of the main vessels, usually on the proximal side of the aneurism, was much vaunted by the Dublin school of surgeons in the last century, and gave not a few good results. It may be applied either continuously or at intervals.

2. **Ligature** of the main vessels leading to or coming from the aneurismal sac must next be considered. The oldest procedure, the **Operation of Antyllus,** consisted in laying open the sac, turning out the clots, securing the vessel above and below, and allowing the wound to heal by granulation (Fig. 131, A). Performed, as it was originally, without antiseptics, it was naturally attended with great mortality from secondary hæmorrhage.

In **Anel's Method** (Fig. 131, B) the artery was tied just above the sac on the cardiac side, with no branch intervening; this also proved dangerous, since secondary hæmorrhage frequently resulted, either from suppuration within the sac, or from injury to the sac during the operation, or from yielding of the arterial wall at the site of ligature from septic periarteritis. At the present time it is not unfrequently undertaken successfully.

Hunter's Operation (Fig. 131, C), which consists of ligature of the main vessel on the cardiac side at some distance from the aneurism, was first performed by him in 1785. The object is not to cut off absolutely the blood-supply to the sac, but to allow the blood to enter it with a greatly diminished impulse, and in small amount at first, thus permitting of the contraction of the sac wall and of the gradual deposit within it of fibrinous clot, which in time becomes organized into a mass of firm fibroid tissue. It is desirable, though not essential, that no branch of large size should intervene between the point of ligature and the sac.

Distal Ligature is only practised for aneurisms situated in positions where it is impracticable to deal with the artery on the cardiac side

of the sac, such as the innominate, lower part of the carotid, or first part of the subclavian. **Brasdor's Operation** consists in tying the main trunk beyond the sac, so as totally to cut off the circulation through it (Fig. 131, D). In **Wardrop's Operation** a ligature is placed on one or more of the distal branches (Fig. 131, E). In the former the sac gradually contracts, and thus allows of the deposit of fibrin; in the latter proceeding, where the circulation is only partly controlled, the diminution of the size of the aneurism goes on much more slowly, and the chances of the deposition of clot in the sac are correspondingly lessened.

It is not unusual, after the application of a ligature to a main artery for aneurism, to observe a **return of pulsation in the sac** after a day or two. In the majority of cases this only continues for a short time, and is by no means an unfavourable sign, indicating the re-establishment of the collateral circulation; but if it commences a week or ten days

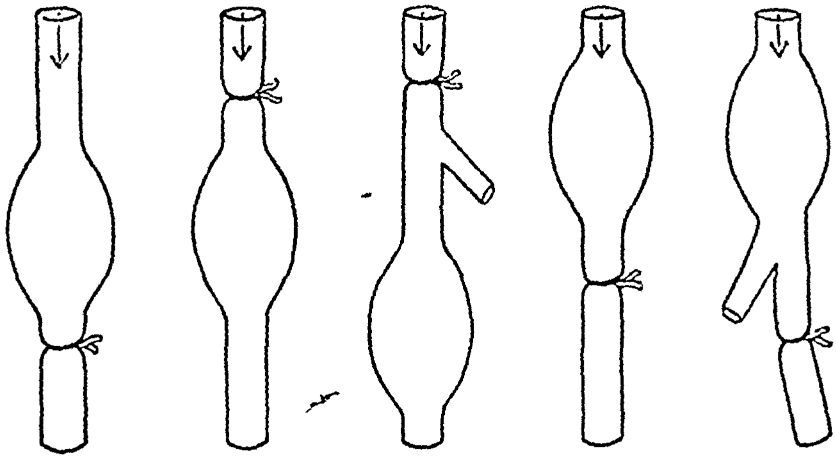


FIG. 131.—METHODS OF APPLYING LIGATURES FOR ANEURISMS.
A, Method of Antyllus; B, Anel's operation; C, the Hunterian operation; D, Brasdor's operation; E, Wardrop's method.

after the operation, it is more likely to persist. It is most frequently seen in cases where the main vessel has been tied at some distance from the sac, as in the superficial femoral for popliteal aneurism, and where one or more large and important collateral branches carry blood into the artery below the ligature or directly into the sac. The early recurrence of pulsation needs no *treatment* in most instances; but when it comes on at a later stage it demands serious attention. Rest, elevation of the limb, and judicious pressure over the trunk above the site of ligature, should first be tried. These failing, the following courses are open: (*a*) The artery may be again tied, either nearer the sac when feasible, or further away from it; (*b*) where the aneurism can be reached, it may be cut down on and dissected out, the best course to adopt if it be practicable; or (*c*) amputation just above the aneurism may be called for as a last resource.

3. **The Introduction of Foreign Bodies into the Sac** (*Moore's Method*,

has not been followed by much success, although a few cases of abdominal aneurism seem to have derived temporary benefit from it. Steel wire has been usually employed; it is firmly wound round a cotton reel (a spool) to give it a spiral coil, and inserted into the sac through a very fine cannula or a hypodermic needle. Varying lengths from 10 feet to 26 yards have been introduced. An ingenious contrivance has been designed by Sir D'Arcy Power and Mr. Colt for this purpose. It consists of a fine wire wisp or cage, which can be introduced closed as a cartridge through a special cannula, and pushed by a ramrod into the sac, where it expands of itself umbrella-fashion, thereby exposing a large surface of wire on which coagulation can occur. Satisfactory results have attended its employment.

D. **Amputation** may be required in the treatment of aneurisms under a variety of circumstances: (*a*) When extensive gangrene of the limb has occurred or is imminent; (*b*) for diffusion or suppuration of an aneurism when everything else has failed; (*c*) for secondary hæmorrhage as a last resource; (*d*) in some cases of recurrent aneurism; (*e*) when joints have been opened or bones eroded to such an extent as to impair the utility of the limb; and, finally, (*f*) in a few cases of subclavian aneurism amputation at the shoulder-joint has been practised in order to diminish the amount of blood flowing through the sac.

The Treatment of a Diffuse Aneurism varies somewhat according to whether the diffusion is slow or rapid. In a *leaking* aneurism the main vessel leading to the swelling must be tied, if this has not already been undertaken, and the influence of this measure, combined with rest, elevation, and careful general treatment, observed. Should the process not be stayed, the case is treated as a diffuse or *ruptured* aneurism by laying open the sac, after exsanguinating the limb by elevation and the use of an elastic band, and securing, if possible, the main vessel above and below, as also any branches which may open into the sac, if they can be found. If there is any evidence of incipient gangrene, or if secondary hæmorrhage supervenes, amputation must be undertaken.

The Treatment of an Inflamed Aneurism is always a matter of anxiety from the risk of recurrent and fatal hæmorrhage. If the main trunk has not been previously tied, this should at once be undertaken so as to reduce the blood-pressure in the sac, and the effect carefully watched; an ice-bag should also be applied to the part, and the limb elevated. If no good result follows, or if the artery has already been tied, nothing remains but to lay the sac freely open and endeavour to secure, by ligature, the main trunk above and below, as well as any smaller branches. Unfortunately, the walls are often soft, so that ligatures cut out; should bleeding supervene, amputation will be required.

Special Aneurisms.

Aneurism of the Thoracic Aorta is most commonly of the fusiform type in the early stages, but a limited sacculation often supervenes as the disease advances. The symptoms vary with the part affected.

(1) In the *ascending part of the arch* the swelling rarely reaches a great size, especially if it is intrapericardial, the sac usually rupturing before marked pressure signs are evident.

(2) When arising from the *transverse part of the arch*, the symptoms vary with the direction taken by the enlargement. If it projects *upwards*, a pulsating tumour may appear at the episternal notch, and cerebral effects may then ensue from interference with the circulation through the carotids, or from pressure on the venous trunks. If it extends *anteriorly*, it may form a large pulsating tumour to the right of the sternum with comparatively slight pressure effects, except the pain arising from its erosion of the thoracic wall. If the enlargement takes place either *posteriorly* or *downwards* within the concavity of the arch, symptoms of dyspnœa and dysphagia are early produced from the close contiguity of the trachea, œsophagus, and pulmonary vessels. Pressure upon the left recurrent laryngeal nerve, as it passes round the aorta, results in spasm of the laryngeal muscles, especially of the crico-arytenoideus posticus, producing suffocative attacks of dyspnœa and a loud metallic or brassy cough, which is very characteristic. At a later date the nerve is paralyzed, and then the voice becomes affected, and the vocal cord fixed and immobile, but without serious dyspnœa. Laryngeal or tracheal stridor may be noticed in these cases, and a dragging down of the trachea synchronous with the heart's action (the so-called 'tracheal tug'). Radiographic examination is a valuable means of diagnosis, since the aneurism gives a dark shadow on the screen or plate.

(3) Aneurisms of the *descending arch* and *thoracic aorta* often attain considerable dimensions, and project posteriorly to the left of the vertebral column, causing a pulsating swelling. The only prominent symptoms are pain, due to erosion of ribs or vertebræ, and interference with deglutition, which may be so great as to suggest the presence of an œsophageal constriction; in fact, before a bougie is passed in any case of dysphagia it is always advisable to make certain by radiography that an aneurism is not present.

Treatment.—Little can be done beyond ordinary medical measures, such as rest, diet, and the administration of iodide of potassium. When the aneurism projects in front, the introduction of coils of iron wire or of Colt's apparatus has been employed with some success.

Ligature of the right carotid and right subclavian, or of the left carotid alone, has been adopted in cases of aneurism of the ascending aorta or of the arch. A certain amount of improvement followed some of the operations, but it is quite possible that this was as much due to the enforced rest in bed as to the operation.

Innominate Aneurism is usually of the tubular variety, and frequently associated with a similar enlargement of the aorta. It presents a pulsating tumour behind the right sterno-clavicular articulation, *i.e.* between the heads of origin of the sterno-mastoid, projecting either into the episternal notch or outwards into the subclavian triangle, and perhaps pushing the clavicle forwards. The *pulse* in both the right temporal and radial arteries is diminished; *œdema* of a brawny character of the right side of the head and neck, and of the right arm, is caused

by pressure on the right innominate vein, whilst less commonly similar changes on the left side may follow compression of the left vein or of the superior vena cava; *pain* shooting into the neck and arm is often produced by implication of the brachial nerves; hyperæmia and sweating of the right side of the face with dilatation of the right pupil may result from irritation of the sympathetic trunk. *Dyspnœa* is induced by direct pressure on the trachea, which may be displaced or flattened, or by compression of the right recurrent laryngeal nerve. *Dysphagia* occurs from pressure on the œsophagus. The course of the case is slowly progressive, and death most commonly results from asphyxia or from rupture of the sac.

Treatment.—Rest and the administration of large doses of iodide of potassium may cause improvement, but distal ligature is the most hopeful proceeding. It is obviously impossible to cut off all the blood passing through the sac to the three main divisions, *viz.* the carotid, subclavian, and vertebral, with safety to the patient (Fig. 132). Ligature of any one of these by itself offers but little prospect of improvement.

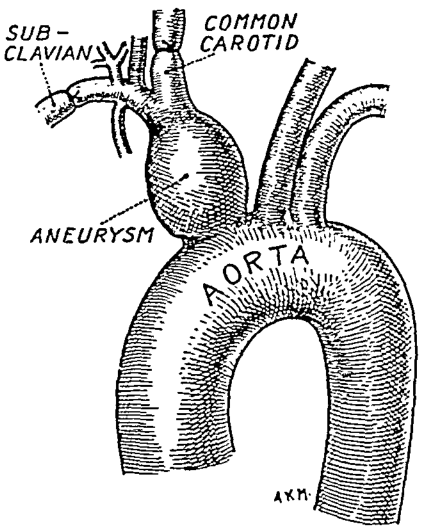


FIG. 132.—APPLICATION OF LIGATURES FOR INNOMINATE ANEURISM.

Aneurism of the Common Carotid is usually situated at the upper part of the trunk near the bifurcation, and more often on the right than on the left side. The root of the right carotid is also not unfrequently dilated, but the intrathoracic portion of the left carotid is rarely affected, except in conjunction with the aorta. No other external vessel is so frequently the seat of aneurism in women. The ordinary intrinsic *signs* of an aneurism are present, and the pressure symptoms are mainly referable to interference with the cerebral circulation, to irritation of the cervical sympathetic trunk, or to pressure upon the larynx, pharynx, or trachea. The progress of these cases is usually slow.

Diagnosis.—(1) *From similar disease at the root of the neck* the distinction is often made with difficulty, since either an aortic, innominate, or subclavian aneurism may push upwards so as to simulate it somewhat closely. Percussion and auscultation of the upper part of the chest, together with a careful investigation into the history of the case, and a digital examination of the limits of the pulsating mass, may suffice to determine the point. The *pressure effects* must also be carefully considered. 'Pressure on the left recurrent laryngeal nerve would distinguish an aortic aneurism from one on the right vessels; pressure on the right nerve in like manner excludes an aortic aneurism. Pressure on the left innominate vein indicates aortic aneurism rather than innominate; compression of the internal jugular or subclavian

vein only points to carotid or subclavian aneurism. A "tracheal tug" indicates an aneurism of the aorta.' The differences in the *peripheral pulses* in the radial and temporal arteries may also give useful information. If the left radial pulse is alone aneurismal, the root of the left subclavian is diseased, whilst if the left temporal is also affected, it suggests an aneurism of the transverse part of the arch beyond the innominate. When both radial and temporal vessels on the right side show signs of interference with the pulse, innominate aneurism is probably present, whilst an affection of only one of these branches indicates that the corresponding carotid or subclavian is dilated. (2) From *abscess, tumours, or enlarged glands* with a transmitted impulse, a carotid aneurism is recognized by an application of the general principles detailed above (p. 327). (3) *Pulsating or cystic goitre* may be distinguished from a carotid aneurism by noting that the goitre is not as a rule limited to one side of the neck, the isthmus being also involved; that the most fixed part of the tumour is in the median line, and not under the sterno-mastoid muscle; and that the swelling moves up and down during deglutition, an aneurism remaining fixed. (4) An aneurism close to the bifurcation may be simulated by an *abnormal arrangement of the terminal branches*, the external carotid crossing the internal from behind forwards, and being pushed outwards sufficiently to cause a pulsating swelling beneath the skin. This condition is usually symmetrical, and can be recognized by careful palpation.

Treatment.—*Ligature* of the carotid above or below the omo-hyoid is the treatment usually adopted, and generally with great success. If the aneurism is near the root of the neck, the distal operation must be undertaken.

Aneurism of the External Carotid is seldom met with, except as an extension of one involving the bifurcation. The usual phenomena are presented near the angle of the jaw, and well above the thyroid cartilage. Pressure results are early experienced, *e.g.* paralysis of one side of the tongue through implication of the hypoglossal nerve, aphonia, or dysphagia. In suitable cases the sac may be dissected out after securing the branches arising from it; failing this, the common trunk must be tied.

Aneurism of the Internal Carotid (extracranial portion) presents symptoms which closely resemble those caused by an aneurism of the bifurcation or of the external carotid, except that the swelling projects more into the pharynx, from which it is separated merely by the pharyngeal wall. It appears as a tense pulsating tumour, placed immediately under the mucous membrane, and looking dangerously like an abscess of the tonsil. The **Treatment** consists in tying the common carotid.

Intracranial Aneurism occurs more commonly upon the internal carotid and its branches than upon those arising from the vertebrals, although the basilar artery is more often affected than any other single vessel. Some intracranial aneurisms can be beautifully demonstrated by the injection of thorotrast into the common carotid artery and then taking a skiagram (Fig. 133). However, if the aneurism

has become consolidated, no outline can be obtained, as in Fig. 134. The aneurisms are generally fusiform in character, and their origin

FIG. 133.—ARTERIOGRAM SHOWING SMALL ANEURISM OF THE MIDDLE CEREBRAL ARTERY.

is often obscure, being attributed to a blow or fall; in children they are stated to result from the lodgment of infected emboli. They sometimes cause no symptoms until the patient is suddenly seized with

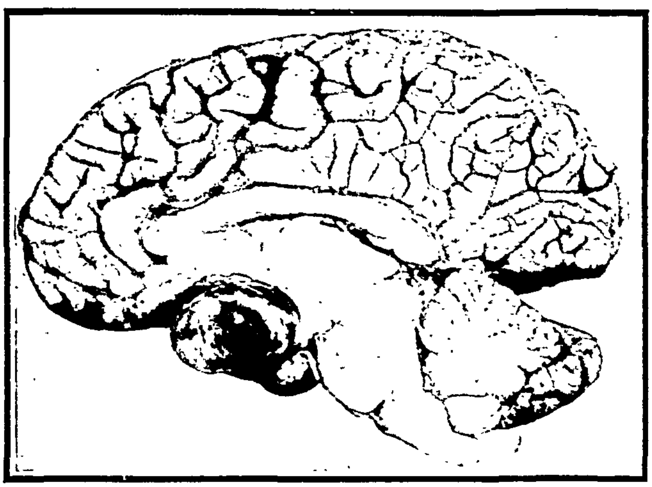


FIG. 134.—ANEURISM OF THE ANTERIOR COMMUNICATING ARTERY OF THE CIRCLE OF WILLIS.
The whole aneurismal sac is filled with laminated clot.

a rapidly fatal apoplexy from rupture of the sac. Symptoms, if present, are due rather to compression of the brain than to erosion

of the more resistant bony structures. Pain which is more or less fixed and continuous may be complained of, or there may be a feeling of pulsation, or of opening and shutting the top of the skull. Sight, hearing, and other functions of the brain may also be impaired, but physical changes in the eyes, such as optic neuritis or atrophy, are not induced, unless there is direct pressure on some part of the optic tract. Occasionally a loud whizzing bruit may be heard on auscultating the skull. The only **Treatment** possible, if a diagnosis can be established, is ligature of the internal carotid artery. Dandy has

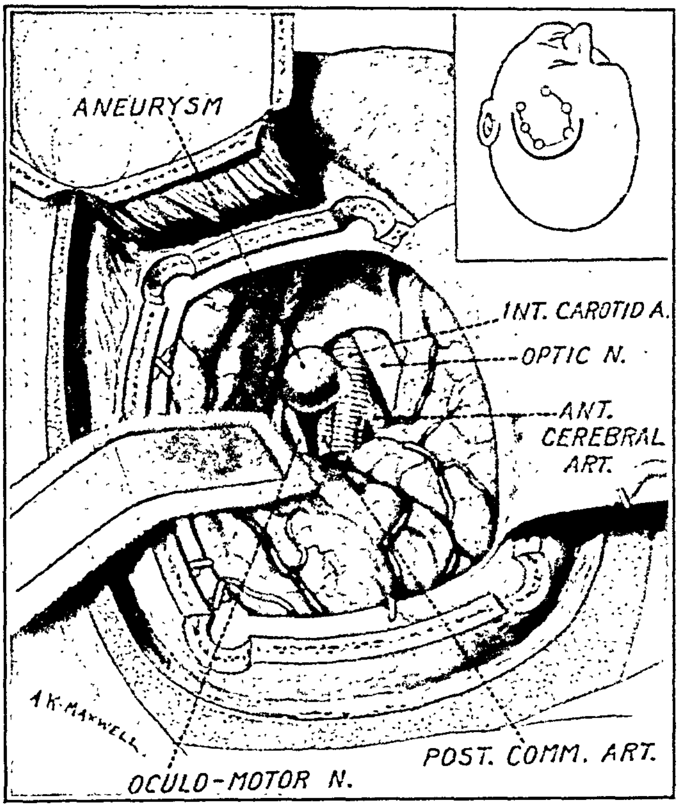


FIG. 135.—EXPOSURE OF AN ANEURISM OF THE INTERNAL CAROTID ARTERY WITHIN THE CRANIUM. THE INSET SHOWS THE SITE OF THE OSTEOPLASTIC FLAP.

reported some successful cases in which he has exposed the aneurism through an osteoplastic flap exposure and then placed a silver clip on the base of the aneurismal sac (Fig. 135).

Orbital Aneurism.—Protrusion of the eyeball, together with pulsation (Fig. 136), which can be felt or even seen (*pulsating exophthalmos*), is always an indication that some vascular lesion is present within the orbit. (*a*) It is occasionally *congenital*, and then probably due to the presence of a deep cavernous angioma. (*b*) It is most frequently *traumatic* in origin, resulting from a penetrating wound, or a blow on the head, which may have caused a fracture of the base of the skull;

in these the lesion present is generally an aneurismal varix between the internal carotid and the cavernous sinus. (*c*) It may be *non-traumatic*, and result from an aneurism of the ophthalmic artery, or from thrombosis of the cavernous sinus. The patient complains of intra-orbital pain and tension; the conjunctival and retinal vessels are distended, and a marked bruit may be present on auscultation. The movements of the eyeball are limited, vision is impaired, and the cornea may become opaque from exposure; finally, the whole globe may be disorganized.

In some cases an aneurism follows a hæmatoma of the retrobulbar tissues due to trauma (Fig. 137).

Diagnosis.—Sarcoma of the orbital wall may exhibit many of the characters of intra-orbital aneurism. Careful palpation will, however, generally demonstrate the existence of a definite tumour; the pulsation, moreover, is less marked, and the bruit less distinct. The distortion of the eyeball and ocular axis is often considerable in malignant tumours, but vision is not so early affected.

FIG. 136.—PULSATING EXOPHTHALMOS FROM TRAUMATIC INTRA-ORBITAL ARTERIO-VENOUS ANEURISM.

Treatment.—Ligature of the internal carotid is the only means which holds out any prospect of benefit, except in the congenital cases, where electrolysis has been very successful.

Subclavian Aneurism is most frequently seen in men, and particularly in those who carry weights on their shoulders; the right vessel is more often affected than the left. Any part of the artery may be involved, but the greatest dilatation naturally occurs in the third portion. A pulsating tumour develops in the subclavian triangle, which may project above the clavicle, but often extends backwards, outwards, and downwards, causing pressure effects upon the veins and nerves of the arm, and also hiccough by irritation of the phrenic. Occasionally it encroaches on the dome of the pleura and apex of the lung, and has been known to burst into the pleural cavity.

The **Treatment** of subclavian aneurism is surrounded with difficulties, and the results hitherto obtained have been most unsatisfactory. *Extirpation* has been undertaken with success, with or without turning up the middle third of the clavicle, as also Matas' operation, but the aneurism is seldom sufficiently limited to allow of these proceedings. *Ligature of the innominate trunk* suggests itself as the operation to be adopted for cure by the Hunterian method, and recent records would certainly encourage one to repeat it in any suitable case, combined with simultaneous ligature of the carotid, so as to avoid backflow of blood. *Ligature of the first part of the subclavian* is occasionally possible,

and a few successful cases have now been reported, although the first nineteen cases in which it was attempted died.

Axillary Aneurism is usually the result of falls on the outstretched arm, or injuries to the shoulders, such as fractures or dislocations, or of attempts to reduce them. A pulsating tumour develops, and its pressure causes pain, local and neuralgic, or œdema of the arm. When the upper part of the vessel is affected, the pulsation is felt immediately below the clavicle, and may project up into the neck, displacing the clavicle forwards; if placed lower down, the aneurism occupies the axilla. The progress of the case is often rapid, and the thoracic cavity may even be encroached on.

Treatment.—Compression (digital) or ligature of the third part of

FIG. 137.—HÆMATOMA OF THE RETRO-BULBAR TISSUES DUE TO A BLOW ON THE ORBIT. UNILATERAL EXOPHTHALMOS IS PRODUCED.

the subclavian artery is required, but if the aneurismal sac extends under the clavicle, it may be necessary to secure the second part of the artery, due care being taken of the phrenic nerve.

Aneurisms of the brachial artery, or of any of the vessels of the forearm, require no special notice. They are almost invariably traumatic in origin, and should be treated by extirpation.

Abdominal Aneurism.—The abdominal aorta may become the seat of aneurism, either at the upper part near the cœliac axis, or at the bifurcation. A pulsating tumour is observed near the middle line, and either close to the umbilicus or in the epigastric notch; the pulsation is expansile in type, and remains the same in character whatever

the position of the patient. Pain, localized in the back from erosion of the vertebræ, or neuralgic from pressure on the solar plexus or lumbar nerves, is the chief symptom, whilst œdema of the lower extremities may arise from compression of the vena cava. There may be some concurrent derangement of the intestinal functions. Occasionally aneurisms form independently on the splenic, hepatic, or mesenteric vessels. **Diagnosis.**—Many conditions give rise to epigastric pulsation. Cardiac pulsation may be felt in the epigastrium when the heart is dilated, but should be easily recognized; as also an impulse transmitted from the aorta through a collection of fæces or a cancerous growth.

Treatment.—Failing medical treatment by rest and diet, *compression* was formerly relied on, being applied either on the distal or proximal aspect of the sac. The method is, however, clumsy and liable to bruise the abdominal viscera. The introduction of Colt's appliance or wiring by Moore's method may be attempted.

Iliac or **Inguinal Aneurism** arises from either the common or external iliac, or from the common femoral; it is frequently sacculated in type and lobulated in shape owing to the pressure of fascial or other structures. The symptoms are very typical, and diffusion is certain to ensue sooner or later. The **Diagnosis** cannot be well mistaken in the early stages, but later on, and specially when situated high in the iliac fossa, it may be difficult to distinguish from a pulsating sarcoma.

Treatment.—*Extirpation* is, of course, the best plan to adopt if it be possible, but more frequently one must depend on proximal *ligature*. For an inguinal aneurism, the external iliac may be tied with every prospect of success. If the aneurism is situated higher, ligature of the common iliac may be undertaken (transperitoneal operation), or even of the aorta. The latter operation has been performed in ten instances, and in all a fatal result followed, although two patients lived thirty-nine and forty-eight days respectively. Failing any of these methods, *compression* of the aorta or common iliac may be employed.

Aneurisms of the Gluteal and Sciatic Arteries are usually traumatic in origin, and present as pulsating swellings in the buttock, the gluteal situated at the upper part of the sciatic notch, whilst the sciatic lies more deeply, and may be partly intrapelvic. Pain in the limb from pressure on the sciatic nerve is a prominent symptom, especially in the sciatic variety. The **Diagnosis** is by no means easy, especially from a pulsating sarcoma.

Treatment.—When the diagnosis is established, transperitoneal ligature of the internal iliac artery should always be adopted. If the sac is laid open from the buttock as a result of a mistaken diagnosis, the old-fashioned plan of treatment must be followed, *viz.* to turn out the clots and secure the bleeding-points.

Femoral Aneurism is the title given to one forming in the course of the superficial femoral artery. It is not uncommonly tubular, and occurs almost invariably in males.

Treatment consists either in extirpation, or ligature of the common or superficial femoral trunk.

Popliteal Aneurism occurs almost invariably in men, constituting a pulsating tumour in the ham, rendering the knee painful and stiff, and so much do the symptoms resemble those of chronic rheumatism that in every such case the popliteal space should be examined. The limb is usually kept semiflexed, and the aneurism often increases rapidly in size. If the main swelling is situated in front of the vessel, there is some likelihood of the knee-joint becoming implicated and neighbouring bones carious; when it extends posteriorly, diffusion is not uncommonly followed by gangrene, on account of the pressure exercised, not only upon the vein, but also upon the articular branches of the popliteal artery, which are most important factors in maintaining the collateral circulation. The **Diagnosis** has to be made from chronic enlargement and abscess of the popliteal glands; but in these there is less disturbance of the circulation in the foot; from bursal tumours, by their want of mobility and pulsation; or from solid tumours, *e.g.* pulsating sarcoma of the femur or tibia, by attention to the general principles already enunciated.

Treatment.—Compression has been eminently successful in many of these cases. Ligature of the femoral artery at the apex of Scarpa's triangle is, however, the plan most commonly adopted, and with the greatest success. In cases where either of these methods has failed, or where the aneurism has become diffuse or recurred, extirpation of the sac is the best course to adopt.

Ligature of Vessels.

This operation is performed to arrest the flow of blood to the periphery, in order either to check hæmorrhage, or to promote the cure of an aneurism, or to diminish the rate of growth of some tumour, or to influence beneficially some peripheral organ by reducing its blood-supply, or as a preliminary to removing some vascular structure, such as the tongue.

Operation.—The artery is examined as far as is possible, so that a healthy portion may be selected for applying the ligature. The various structures (*rallying-points*) met with on the way to the artery are recognized, and drawn aside, if need be, so as to lay bare the sheath of the vessel, which is opened over the artery by a longitudinal incision about ¾ inch in length. The aneurism needle is inserted unarmed, and gently manipulated up and down, so as to free the vessel all round, a matter of no great difficulty if the sheath has been correctly opened and the arterial wall exposed. The ligature may then be passed through the eye of the needle, and carried round the vessel, tied in a direction exactly at right angles to the longitudinal axis; in doing so the artery must not be dragged out of its sheath, but the ligature should be tightened by the tips of the forefingers meeting upon it. The opening in the sheath should be closed over the ligature by a fine buried stitch, and the various structures displaced in reaching the vessel are similarly secured in good position.

Method of Application of the Ligature.—In the smaller vessels and those of medium size all that is needed for security is a **reef** knot tied

the position of the patient. Pain, localized in the back from erosion of the vertebræ, or neuralgic from pressure on the solar plexus or lumbar nerves, is the chief symptom, whilst œdema of the lower extremities may arise from compression of the vena cava. There may be some concurrent derangement of the intestinal functions. Occasionally aneurisms form independently on the splenic, hepatic, or mesenteric vessels. **Diagnosis.**—Many conditions give rise to epigastric pulsation. Cardiac pulsation may be felt in the epigastrium when the heart is dilated, but should be easily recognized; as also an impulse transmitted from the aorta through a collection of fæces or a cancerous growth.

Treatment.—Failing medical treatment by rest and diet, *compression* was formerly relied on, being applied either on the distal or proximal aspect of the sac. The method is, however, clumsy and liable to bruise the abdominal viscera. The introduction of Colt's appliance or wiring by Moore's method may be attempted.

Iliac or **Inguinal Aneurism** arises from either the common or external iliac, or from the common femoral; it is frequently sacculated in type and lobulated in shape owing to the pressure of fascial or other structures. The symptoms are very typical, and diffusion is certain to ensue sooner or later. The **Diagnosis** cannot be well mistaken in the early stages, but later on, and specially when situated high in the iliac fossa, it may be difficult to distinguish from a pulsating sarcoma.

Treatment.—*Extirpation* is, of course, the best plan to adopt if it be possible, but more frequently one must depend on proximal *ligature*. For an inguinal aneurism, the external iliac may be tied with every prospect of success. If the aneurism is situated higher, ligature of the common iliac may be undertaken (transperitoneal operation), or even of the aorta. The latter operation has been performed in ten instances, and in all a fatal result followed, although two patients lived thirty-nine and forty-eight days respectively. Failing any of these methods, *compression* of the aorta or common iliac may be employed.

Aneurisms of the Gluteal and Sciatic Arteries are usually traumatic in origin, and present as pulsating swellings in the buttock, the gluteal situated at the upper part of the sciatic notch, whilst the sciatic lies more deeply, and may be partly intrapelvic. Pain in the limb from pressure on the sciatic nerve is a prominent symptom, especially in the sciatic variety. The **Diagnosis** is by no means easy, especially from a pulsating sarcoma.

Treatment.—When the diagnosis is established, transperitoneal ligature of the internal iliac artery should always be adopted. If the sac is laid open from the buttock as a result of a mistaken diagnosis, the old-fashioned plan of treatment must be followed, *viz.* to turn out the clots and secure the bleeding-points.

Femoral Aneurism is the title given to one forming in the course of the superficial femoral artery. It is not uncommonly tubular, and occurs almost invariably in males.

Treatment consists either in extirpation, or ligature of the common or superficial femoral trunk.

Popliteal Aneurism occurs almost invariably in men, constituting a pulsating tumour in the ham, rendering the knee painful and stiff, and so much do the symptoms resemble those of chronic rheumatism that in every such case the popliteal space should be examined. The limb is usually kept semiflexed, and the aneurism often increases rapidly in size. If the main swelling is situated in front of the vessel, there is some likelihood of the knee-joint becoming implicated and neighbouring bones carious; when it extends posteriorly, diffusion is not uncommonly followed by gangrene, on account of the pressure exercised, not only upon the vein, but also upon the articular branches of the popliteal artery, which are most important factors in maintaining the collateral circulation. The **Diagnosis** has to be made from chronic enlargement and abscess of the popliteal glands; but in these there is less disturbance of the circulation in the foot; from bursal tumours, by their want of mobility and pulsation; or from solid tumours, *e.g.* pulsating sarcoma of the femur or tibia, by attention to the general principles already enunciated.

Treatment.—Compression has been eminently successful in many of these cases. Ligature of the femoral artery at the apex of Scarpa's triangle is, however, the plan most commonly adopted, and with the greatest success. In cases where either of these methods has failed, or where the aneurism has become diffuse or recurred, extirpation of the sac is the best course to adopt.

Ligature of Vessels.

This operation is performed to arrest the flow of blood to the periphery, in order either to check hæmorrhage, or to promote the cure of an aneurism, or to diminish the rate of growth of some tumour, or to influence beneficially some peripheral organ by reducing its blood-supply, or as a preliminary to removing some vascular structure, such as the tongue.

Operation.—The artery is examined as far as is possible, so that a healthy portion may be selected for applying the ligature. The various structures (*rallying-points*) met with on the way to the artery are recognized, and drawn aside, if need be, so as to lay bare the sheath of the vessel, which is opened over the artery by a longitudinal incision about ¾ inch in length. The aneurism needle is inserted unarmed, and gently manipulated up and down, so as to free the vessel all round, a matter of no great difficulty if the sheath has been correctly opened and the arterial wall exposed. The ligature may then be passed through the eye of the needle, and carried round the vessel, tied in a direction exactly at right angles to the longitudinal axis; in doing so the artery must not be dragged out of its sheath, but the ligature should be tightened by the tips of the forefingers meeting upon it. The opening in the sheath should be closed over the ligature by a fine buried stitch, and the various structures displaced in reaching the vessel are similarly secured in good position.

Method of Application of the Ligature.—In the smaller vessels and those of medium size all that is needed for security is a **reef** knot tied

firmly; but in the largest trunks, *e.g.* the innominate, first part of the subclavian, and common iliac, it is advisable to employ what is termed the **stay knot** (Fig. 138). Two strands of ligature are passed round the vessel side by side and half-knotted; the two ends on each side are then taken up together and tied across in one knot. The degree of tension is such as to approximate completely the vessel walls, but without rupturing the inner or middle coats, thereby minimizing the risks of secondary hæmorrhage.

The rule usually followed is to pass the needle *from important structures, such as the vein,* but really this is a matter of little significance when the above directions have been carefully carried out, and especially in superficial vessels. *Should the vein be accidentally punctured,* the needle must be at once withdrawn and the puncture in the vein secured by ligature, whilst the artery is tied a little higher or lower. In dealing, however, with the smaller vessels, where the venæ comites are in close contact with the arteries, no harm will attend their inclusion in the ligature.

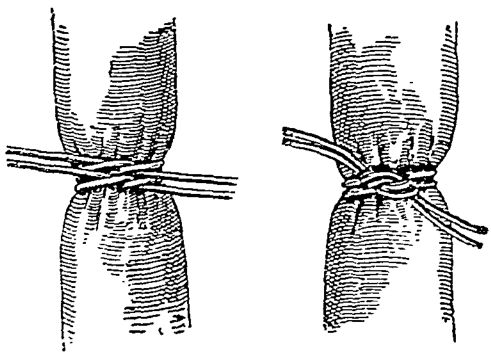


FIG 138.—STAY KNOT.

After-Treatment.—The patient must be kept at rest for at least three weeks in order to secure permanent obliteration of the artery and the effective development of a collateral circulation, especially in dealing with the larger vessels and in elderly people. When the main artery to one of the extremities has been tied, the limb should be wrapped in aseptic wool and slightly raised, and if there is any likelihood of gangrene it should be thoroughly purified.

There are two great **dangers** liable to follow the ligation of an artery in its continuity.

1. **Secondary Hæmorrhage** (*vide* p. 267).

2. **Gangrene** may arise from a variety of causes: (*a*) From simple loss of vitality, owing to a defective collateral circulation, as when the peripheral vessels are calcareous and rigid. The tissues which receive the smallest amount of blood die first, *e.g.* the fingers or toes, or the subcortical white substance of the brain. Severe loss of blood after the operation, as from secondary hæmorrhage, may also determine tissue necrosis. Under such circumstances it almost always takes on the dry form. (*b*) Interference with the venous return, as by injury to the vein during operation, or the pressure of a tight bandage, or thrombosis induced subsequently by infective periphlebitis, was formerly supposed to render the limbs more liable to gangrene, but recent experience has contradicted this idea, and it is possible that simultaneous ligature of the vein may hinder rather than predispose to gangrene by limiting the vascular back-pressure in the limb. (*c*) Unsuitable after-treatment, such as too great elevation of the

limb, the injudicious application of an ice-bag or hot-water bottle during the period of diminished vitality immediately following the operation, or even an attack of erysipelas, may also bring about the death of some of the tissues. The **Treatment** of aseptic gangrene following ligature is expectant in character, the parts being allowed to separate naturally. If, however, there is much pain or any tendency to spread, or if infection is present, giving rise to fever and general disturbance, it is wiser to remove the limb well above the line of demarcation.

The **Innominate Artery** has now been tied with success on at least six occasions out of a total of about thirty operations. For details textbooks on operative surgery must be consulted.

Collateral Circulation.—Intracranial : Vertebrals and carotids in the circle of Willis.

Face and Neck : Branches of the two external carotids across the middle line.

Trunk : First aortic intercostal *with* superior intercostal of subclavian; upper aortic intercostals *with* thoracic branches of axillary and intercostals of internal mammary; deep epigastric and inferior phrenic *with* terminal divisions of internal mammary.

The **Carotid Artery** may be tied either above or below the level at which it is crossed by the anterior belly of the omo-hyoid. The line of the vessel is indicated by that drawn from the sterno-clavicular articulation to a point midway between the angle of the jaw and the tip of the mastoid process, the bifurcation being on a level with the upper border of the thyroid cartilage.

Ligature above the Omo-hyoid.—The vessel is here more superficial, and the ligature is applied on a level with the cricoid cartilage. The patient lies upon the back, with the chin raised and the head turned towards the opposite side. A 3-inch incision is made in the line of the vessel, the centre on a level with the cricoid (Fig. 139). The skin, platysma, and fasciæ are divided, and the anterior edge of the sterno-mastoid defined. The deep fascia is incised along its inner border, so that it may be drawn aside by a retractor; the sterno-mastoid branch of the superior thyroid artery may be divided at this stage. On the inner side of the wound the omo-hyoid muscle must now be looked for, trending forwards and upwards from under cover of the sterno-mastoid. In the angle formed by these two structures the pulsation of the vessel should be felt and the sheath readily recognized, with the descendens cervicis nerve upon it. It is opened on the inner side, and the artery well cleared. The needle is passed from without inwards, and if the sheath has been efficiently opened, the vagus nerve will run no risk of being included.

Ligature below the Omo-hyoid.—A similar incision is made, but lower in the neck, reaching from the cricoid cartilage nearly to the sterno-clavicular joint. The sterno-mastoid is drawn outwards, and perhaps the anterior fibres may need to be divided; the sterno-hyoid and thyroid muscles are retracted inwards or divided, and the omo-hyoid can usually be drawn upwards. The sheath is thus exposed, and opened on the inner side, the needle being passed as in the previous

operation. It must be remembered that both internal jugular veins are directed towards the right side in the lower part of their course, and hence the left vein is likely to lie somewhat in front of the artery. The inferior thyroid veins may also be seen, and need to be drawn aside or ligatured.

Collateral Circulation.—Intracranial: Circle of Willis.

Extracranial: Communications across the middle line of branches of the external carotids and vertebrals; inferior thyroid *with* the superior thyroid; profunda cervicis *with* princeps cervicis of occipital; superficial cervical *with* branches of occipital and vertebral.

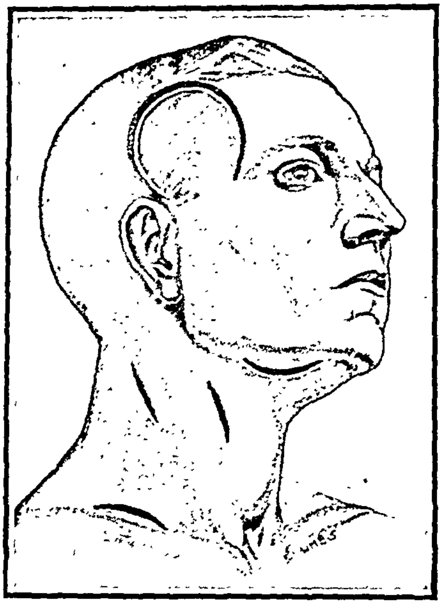


FIG. 139.—INCISIONS FOR OPERATIONS ON VESSELS OF THE NECK.

The upper curved incision is for ligature of the middle meningeal artery. The other incisions are for ligature of a common carotid, subclavian and lingual arteries. The incision behind the sterno-mastoid muscle is for operations on the posterior triangle of the neck.

Ligature of the Internal Carotid.—An incision is made along the anterior border of the sterno-mastoid, its centre being opposite the great cornu of the hyoid bone; the muscle is pulled backwards, and the posterior belly of the digastric is seen and drawn up. The external carotid is displaced forwards, and then the internal carotid in its sheath appears. The latter is opened, and the aneurism needle passed from the jugular vein.

The *Collateral Circulation* to the brain is maintained by the circle of Willis.

Ligature of the External Carotid is occasionally required, the site oi election being between the superior thyroid and lingual branches. An incision is made along the anterior border of the sterno-mastoid, 3 inches in length, its centre corresponding to the great cornu of the hyoid bone. The edge of the muscle is defined and drawn outwards, and the posterior belly of the digastric sought for above, the hypoglossal nerve lying just below it. The sheath is now opened below the tip of the great cornu, and the needle passed from without inwards.

Collateral Circulation.—Vide ligature of the common carotid (extracranial portion).

Ligature of the Lingual Artery may be employed as a preliminary to removal of the tongue for malignant disease. The vessel can be secured either close to its origin from the external carotid, or in the submaxillary triangle under cover of the hyoglossus muscle.

In the Submaxillary Triangle.—The patient lies on his back, with

the shoulders raised, and the head extended backwards and turned to the opposite side. A crescentic incision with its convexity downwards is made, commencing about 1 inch below the symphysis menti, and extending back to the sterno-mastoid, the centre opposite the great cornu of the hyoid bone (Fig. 140). The integument and platysma are divided, the lower border of the submaxillary gland is defined, and along it the deep fascia is incised. The gland is now drawn upwards and held over the margin of the jaw with a retractor (Fig. 140). On opening up the wound thoroughly the two bellies of the digastric muscle are seen converging to the hyoid bone, the anterior belly passing superficial to the fibres of the mylo-hyoid muscle, which course nearly transversely to the mandible, and of which the posterior

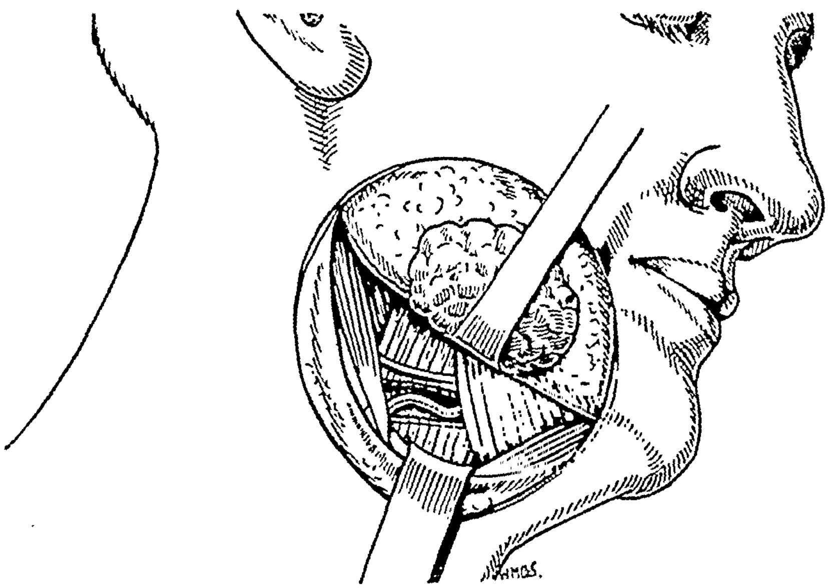


FIG. 140.—LIGATURE OF LINGUAL ARTERY.

The submaxillary gland has been drawn over the side of the jaw with a hook, exposing the hypoglossal nerve. The place where the artery is tied is indicated by a window in the hyoglossus, through which it can be seen.

fibres may be divided with advantage. The digastric tendon is drawn down with a blunt hook, and in the space thus cleared the hyoglossus muscle becomes evident with its fibres passing vertically upwards, and resting upon it the hypoglossal nerve coursing forwards to get under cover of the mylo-hyoid, and either above or below it the ranine vein. The fibres of the hyoglossus are now divided transversely midway between the nerve and the hyoid bone, and in the opening made by their retraction is seen the artery, lying on the middle constrictor.

In the Neck Close to its Origin.—An incision is made along the anterior border of the sterno-mastoid similar to that needed for ligature of the external carotid. The muscle is drawn backwards, and the great cornu of the hyoid bone defined. The small space is now cleared between that bony process and the posterior belly

of the digastric, in which the artery can be felt resting upon the middle constrictor, and secured just as it rises from the external carotid.

The **Facial Artery** may be exposed and tied through a horizontal incision, 1 inch in length, made directly over the vessel as it crosses the lower border of the jaw immediately in front of the masseter.

The **Temporal Artery** is reached in front of the auditory meatus through a vertical incision, and must be carefully isolated from the auriculo-temporal nerve.

The **Occipital Artery** is tied through an incision extending from the apex of the mastoid process backwards for about 2 inches towards the occipital protuberance. The posterior fibres of the sterno-mastoid, the splenius, and trachelo-mastoid, are divided so as to expose the artery as it emerges from the groove on the under surface of the mastoid process, where it is easily secured.

The **Subclavian Artery** has been tied in each part of its course, but most frequently in the third. Ligatures of the first and second parts are such unusual proceedings that we must refer students to larger textbooks for descriptions.

For *ligature of the third part* the patient is placed on the back, close to the edge of the table; the arm is well depressed, and the head turned to the opposite side. The skin is drawn down by the left hand, and an incision 3 or 4 inches long made over the clavicle (Fig. 139). On releasing the skin it retracts upwards, so that the wound comes to be situated about ½ inch above the clavicle, and thus the external jugular vein is more efficiently protected. The incision should be placed with its centre about 1 inch to the inner side of the middle of the clavicle, and should expose the space between the sterno-mastoid and trapezius muscles, the fibres of which are divided to a suitable extent if they encroach abnormally upon the bone. The external jugular and other veins often give the surgeon much trouble; they are either drawn aside or, if necessary, divided between ligatures. The deep fascia is incised in the line of the wound, care being taken to avoid the transverse cervical and suprascapular arteries, the former of which is above the line of operation, whilst the latter is hidden behind the clavicle. The posterior belly of the omo-hyoid, if seen at all, is drawn upwards. Various layers of fascia must be carefully cut or torn through until the nerves of the brachial plexus appear; the finger can then readily define the scalene tubercle on the first rib. The subclavian vein is situated in front of the finger, but on a lower level, whilst the artery itself can be detected pulsating under the pulp of the finger between it and the rib. The cords of the brachial plexus are placed above and external to it, the lower cord passing down behind. The needle is insinuated from above downwards, and must be kept very close to the artery to prevent all possibility of including the lowest cord of the plexus.

Collateral Circulation.—*Thoracic set:* Branches of the aortic intercostals and internal mammary *with* thoracic branches of axillary.

Scapular set: Suprascapular and posterior scapular *with* subscapular and its dorsalis branch in the venter or on the dorsum of scapula.

Acromial set: Suprascapular *with* acromio-thoracic.

The **Internal Mammary Artery** may be exposed and tied by dividing the intercostal aponeurosis and muscles for an inch or more from the outer edge of the sternum, from which it is distant about ½ inch.

Ligature of the Vertebral Artery has been undertaken for wounds, for secondary hæmorrhage after ligature of the innominate, and in the treatment of epilepsy, but without much permanent benefit in the last case. An incision is made along the lower half of the posterior border of the sterno-mastoid, the platysma and deep fascia are divided, and the muscle drawn forwards. The scalenus anticus is clearly defined, together with the phrenic nerve. The interval between it and the longus colli muscle can now be demonstrated with the ascending cervical artery lying upon it. The anterior transverse process of the sixth cervical vertebra must be made out. Just below this the vertebral vessels are found entering the canal in the transverse process, and the vein, which is placed anteriorly, is drawn outwards to allow the needle to be passed from without inwards. A few sympathetic twigs are often included in the ligature, and may cause contraction of the pupil.

Ligature of the Thyroid Vessels is sometimes used in the treatment of exophthalmic goitre (*q.v.*).

The **Axillary Artery** is tied for punctured wounds of the axilla, as a distal operation for subclavian aneurism, occasionally for wounds of the palmar arch, and possibly for secondary hæmorrhage from the brachial. Two classical operations are described and practised in classes on operative surgery.

1. *Ligature of the first part of the vessel* is usually undertaken through a curved incision, with its concavity upwards, extending from the coracoid process to just below the sterno-clavicular joint. The clavicular origin of the pectoralis major is divided, and the costo-coracoid membrane exposed and divided. Branches of the acromio-thoracic axis are displaced, and the main trunk is exposed by a blunt dissector and forceps. The vein lies within and below, and the cords of the brachial plexus above and to the outer side. The divided muscular fibres should be subsequently sutured together.

2. *Ligature of the third part of the artery* is performed from the axilla. The arm is fully abducted, and the surgeon stands between it and the body. An incision is made in the course of the vessel (Fig. 141). The inner border of the coraco-brachialis muscle is clearly defined, and drawn slightly outwards, and the median nerve, together with the musculo-cutaneous trunk, at once comes into view. On drawing these inwards the artery itself is seen, with the vein to the inner side. The needle is passed from the vein.

Collateral Circulation.—If above the acromio-thoracic, the same as for the third part of the subclavian (*q.v.*).

If above the subscapular and circumflex: Long thoracic and inter-

costals *with* thoracic branches of subscapular; suprascapular and posterior scapular *with* scapular branches of subscapular; suprascapular and acromio-thoracic *with* posterior circumflex in the deltoid.

If below the circumflex, same as for ligature of brachial above the superior profunda, *i.e.* posterior circumflex *with* superior profunda in the deltoid.

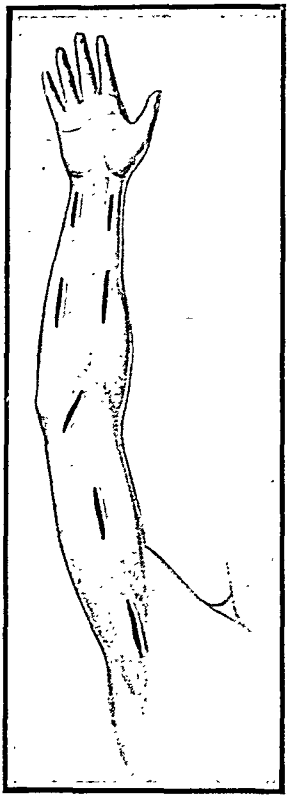


FIG. 141. — INCISIONS FOR TYING THE ARTERIES OF THE ARM.

The incisions from below upwards are for exposing the third part of the axillary, the brachial, the brachial at the bend of the elbow, the radial and ulnar arteries.

The **Brachial Artery** may need to be ligatured for hæmorrhage from the palmar arches, or from a wound in the forearm or about the elbow, for aneurisms, or for arterio-venous wounds at the bend of the elbow. It may be tied in one of two places:

1. *At the Middle of the Arm.*—The arm is held away from the side at a right angle, with the hand supine, but with no support beneath it, for fear of pushing forwards the triceps and displacing the vessel. The surgeon stands between the arm and the trunk. An incision 2 inches long is made in the line of the vessel along the inner border of the biceps muscle (Fig. 141), and the thin fascial investment of the limb divided. The inner edge of the muscle is clearly exposed, and by drawing it slightly forwards the median nerve is brought into view, and perhaps the basilic vein. The nerve, which is at this spot crossing the artery from without inwards, is drawn inwards, and the sheath of the vessel found beneath it. The artery is separated from its venæ comites, and the ligature passed and tied.

2. *At the Bend of the Elbow.*—An oblique incision is made, about 2 inches long, parallel to the inner border of the biceps tendon, its lower end corresponding to the crease of the elbow (Fig. 141). The incision should be placed at an angle of forty-five degrees to the axis of the limb, and to the outside of, and nearly parallel to, the median basilic vein, which, if seen, must be drawn inwards. The bicipital fascia is now incised, and the artery with its venæ comites exposed in the loose fat, the median nerve being well away on the inner side.

Collateral Circulation.—If above the origin of the superior profunda, posterior circumflex in deltoid *with* ascending branches of superior profunda.

If below the origin of the inferior profunda, the anastomoses around the elbow-joint.

The **Ulnar Artery** rarely needs ligature except for palmar hæmorrhage or direct wounds. In the former case the artery can easily be secured

just above the wrist, in the latter case by enlarging the original wound. Various stereotyped operations are described, but are more often seen in the examination-room or dead-house than in the operating theatre. It should be borne in mind that the artery curves inwards from the centre of the bend of the elbow to the radial side of the pisiform bone. The lower two-thirds of its course is indicated by a line drawn from the internal condyle of the humerus to the same spot below.

1. *At the Wrist.*—An incision about 1 inch in length is made directly upwards from the flexure of the wrist in the line of the vessel (Fig. 141). The deep fascia is opened, the tendon of the flexor carpi ulnaris drawn to the inner side, and the vessels are then seen, accompanied by the nerve which lies to the ulnar side of the artery.

2. *In the Middle of the Forearm.*—An incision is made along a line drawn from the anterior edge of the tip of the inner condyle to the radial side of the pisiform bone (Fig. 141). The white line indicating the intermuscular septum between the flexor carpi ulnaris and flexor sublimis digitorum is then sought for and opened up; it is often very slightly marked, and may be difficult to distinguish. If the correct interspace has been opened, the surgeon is directed towards the ulna, and readily finds the vessels under cover of the flexor carpi ulnaris, with the nerve lying a little way to the inner or ulnar side.

3. The upper limit of the ulnar artery can be reached through an oblique incision along the upper border of the pronator teres, thus opening up the ante-cubital fossa, and exposing the bifurcation of the brachial.

Radial Artery.—The line of the vessel extends from the middle of the bend of the elbow to the interspace at the wrist between the flexor carpi radialis and the supinator longus. It then turns outwards, and may be felt beating in the space between the tendons of the extensor primi and extensor secundi internodii muscles.

1. *At the Back of the Wrist* the vessel may be secured by opening up the above-mentioned intertendinous hollow, where the artery is found coursing onwards to the base of the first interosseous space. The incision is placed obliquely between the tendons, extending from the back of the styloid process of the radius to the base of the first metacarpal bone.

2. *Above the Wrist* an incision is made in the line of the vessel (Fig. 141), which is found after division of the fascia between the supinator longus and flexor carpi radialis.

3. *In the Middle or Upper Third of the Forearm* an incision is made in the line of the vessel (Fig. 141), and the inner border of the supinator longus sought for and retracted. The vessels are found under cover of this structure, with the radial nerve to the outer side, though separated by an interval above.

Ligature of the Abdominal Aorta has been undertaken in fourteen instances for severe primary or secondary hæmorrhage, or for diffuse inguinal or iliac aneurism, when no other method of treatment was practicable. All these cases have proved fatal, in most instances from infection and secondary hæmorrhage.

The **Common Iliac Artery** extends for a distance of 2 inches from

the bifurcation of the aorta opposite the left side of the body of the fourth lumbar vertebra to the front of the sacro-iliac synchondrosis. It may be reached through an incision made in the median line with its centre a little below the umbilicus. The vessel is sought for and exposed by an incision through the posterior layer of the parietal peritoneum, and a ligature passed and tied. The ureter which crosses the artery just above its bifurcation must be carefully avoided.

Collateral Circulation.—Blood reaches the *external iliac* and its branches by means of the anastomosis of the lumbar arteries *with* the circumflex iliac, and of the superior epigastric, lumbars, and intercostals *with* the superficial and deep epigastric. The *internal iliac* and its branches are supplied by the union of (*a*) the lumbar branches *with* the ilio-lumbar; (*b*) the middle sacral *with* the lateral sacral; (*c*) the retropubic anastomosis of the two obturator arteries; and (*d*) the communications of the pudic, hæmorrhoidal, and vesical trunks *with* those of the opposite side.

Ligature of the Internal Iliac Artery is occasionally performed for hæmorrhage from, or aneurism of, one of its branches, the gluteal being that most commonly affected. The trunk is a short one, at most 1½ inches in length, and is best reached by opening the abdomen in the middle line below the umbilicus (Fig. 142), pushing aside the intestines, and searching for the bifurcation of the common iliac. The posterior layer of the peritoneum is then carefully incised, the ureter avoided, and an armed aneurism needle passed without wounding the vein.

The *Collateral Circulation* is the same as that given for the internal iliac division of the common iliac.

The **External Iliac Artery** is easily accessible in any part of its course, which measures from 3½ to 4 inches in length; it has but few branches, and those situated low down. Its position is indicated by the lower two-thirds of a line drawn from the bifurcation of the aorta to midway between the anterior superior spine and the symphysis pubis, *i.e.* to a point a little internal to the middle of Poupart's ligament.

Many suggestions as to the best means of reaching the artery have been made, and both trans- and extra-peritoneal methods have been adopted. It is so readily secured, however, by the latter that it seems unnecessary to open the peritoneum. There are two chief forms of extraperitoneal operation.

Astley Cooper's Operation.—An incision is made parallel to the outer half of Poupart's ligament, commencing a little to the inner side of its centre, and ⅜ inch above it, and extending upwards and outwards to about 1 inch internal to the anterior superior spine (Fig. 142). The external oblique aponeurosis is divided along this line, and the exposed lower margins of the internal oblique and transversalis muscles arching over the inguinal canal are drawn upwards by retractors. The transversalis fascia and loose subperitoneal fat are now opened with forceps and director, and the vessel is felt pulsating immediately under the finger. The epigastric and circumflex iliac arteries must not be damaged during this manipulation, since they are important factors in the collateral circulation. The needle is passed from within

outwards, the ligature tied, and the divided muscular and aponeurotic structures united by buried sutures.

Abernethy's Modified Operation is more commonly utilized. The incision, about 4 inches in length, extends from a point $1\frac{1}{2}$ inches within and above the anterior superior iliac spine to just external to, and $\frac{1}{2}$ inch above, the middle of Poupart's ligament (Fig. 142). Through this the aponeurosis of the external oblique is divided along the course of its fibres, as also the internal oblique and transversalis. The transversalis fascia is now carefully incised; it varies considerably in thickness, being sometimes well developed, but is occasionally so attenuated as to be scarcely recognizable. The fingers are now introduced into the wound, and the peritoneum and its contents stripped from the iliac fossa, and drawn inwards and forwards, where they are kept out of the way by a broad spatula. In the space thus opened up one can see the iliacus muscle covered by its fascia, and to its inner side the rounded outline of the psoas. The vessel lies to the inner border of this, and can usually be readily found, enveloped in a fascial sheath, with the genito-crural nerve coursing over it, and perhaps some lymphatic glands upon it. The artery is separated from the vein which lies to the inner side, and the needle passed from within outwards.

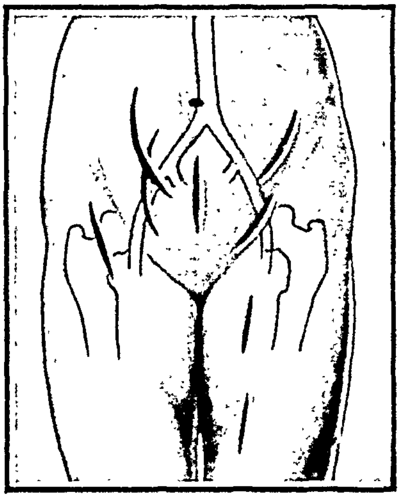


FIG. 142.—INCISIONS FOR OPERATIONS ON LOWER PART OF ABDOMEN AND UPPER PART OF THIGHS.

Collateral Circulation.—Anterior set: Superior epigastric of internal mammary, lumbar, and lower intercostals *with* superficial and deep epigastric in sheath of rectus.

Posterior set: Gluteal and sciatic *with* internal and external circumflex and first perforating of profunda at back of great trochanter (crucial anastomosis).

External set: Ilio-lumbar and gluteal *with* deep and superficial circumflex iliac and ascending branch of external circumflex.

Internal set: Obturator *with* internal circumflex; and terminal divisions of internal pudic *with* superficial and deep external pudic.

The **Common Femoral Artery** is but rarely ligatured, except as a preliminary measure in amputation at the hip-joint, since the number of branches arising from it is likely to interfere with its sound occlusion, and the collateral circulation is better after ligature of the external iliac. It may be reached by a vertical incision over the line of the vessel, extending both a little above and below Poupart's ligament. The superficial lymphatics and veins must be carefully avoided, the fascia lata divided, the sheath exposed and opened, and the ligature passed from the inner side.

Collateral Circulation.—Internal set: Obturator *with* internal circumflex, and internal pudic *with* external pudic.

External set: Circumflex iliac *with* ascending branch of external circumflex.

Posterior set: Gluteal and sciatic *with* internal and external circumflex, and first perforating; comes nervi ischiadici *with* perforating of the profunda and muscular of popliteal.

The **Superficial Femoral Artery** is indicated by a line drawn from midway between the anterior superior spine and the symphysis pubis to the tuberosity of the internal condyle, the limb being flexed, abducted, and everted. It may be secured at 'the site of election,' *i.e.* at the apex of Scarpa's triangle, or in Hunter's canal.

Ligature at the Apex of Scarpa's Triangle.—A 4-inch incision is made in the line of the artery, the centre being about 4 inches (or a hand's breadth) below Poupart's ligament (Fig. 142). The integument and fasciæ are divided, the inner border of the sartorius exposed, and the sheath found immediately behind it, the muscle being drawn slightly outwards; the middle cutaneous nerve is perhaps brought into view. The vein is placed behind the artery at this level.

Collateral Circulation.—External circumflex *with* lower muscular of femoral, anastomotica magna, and superior articular of popliteal.

Profunda femoris by its perforating and terminal branches *with* the muscular and articular branches of femoral and popliteal.

Ligature in Hunter's Canal.—An incision 4 inches in length is made along the line of the artery in the middle of the thigh (Fig. 142). The sartorius is exposed by division of the fascia lata, its fibres running downwards and inwards; its outer border should be defined, and the muscle retracted inwards. The aponeurotic covering of Hunter's canal is now in view, stretching between the adductor longus and vastus internus; it is incised, and the sheath of the vessel found below it, with the nerve to the vastus internus lying to its outer side, the long saphenous nerve crossing it from without inwards, and the vein passing behind it, to become external lower down.

Collateral Circulation is maintained through the profunda and its branches.

The **Popliteal Artery** may be tied either just after it has passed through the adductor opening, or in the depths of the popliteal space, but preferably in the former situation. Neither operation is often required.

To tie the *upper part*, the limb is fully abducted and everted so as to enable the adductor tubercle and tendon of the adductor magnus to be clearly defined. An incision, 4 inches in length, is then made from the tubercle upwards (Fig. 143), and the tendon exposed. The internal saphenous vein and nerve may be seen, but are drawn backwards by means of a broad retractor, together with the sartorius, gracilis, and semi-membranosus. If possible, the branch of the anastomotica magna which courses along the tendon should be spared. The fascial space behind is now opened up, and the artery found surrounded by a good deal of loose connective tissue. The vein is usually seen on the outer side, and is here very thick and dense, so that in the dead subject it can be readily mistaken for the artery.

The *lower part* is tied through an incision in the middle line of the

popliteal space, dividing the deep fascia and drawing out of the way the heads of the gastrocnemius muscle and the internal popliteal nerve. The vein is superficial to the artery, and is found by following the short saphenous trunk.

Collateral Circulation is maintained by the anastomosis around the knee-joint.

The **Posterior Tibial Artery** but seldom requires to be ligatured except for hæmorrhage, or on the face of amputation stumps; hence the operations described below are rarely seen away from the dead-house. The line of the vessel is indicated by one drawn from the

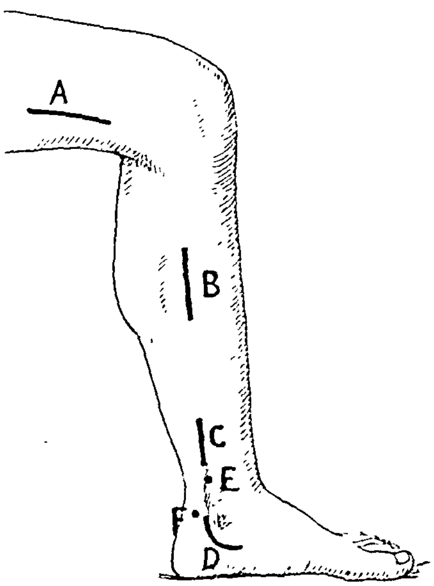


FIG. 143.—INCISIONS FOR LIGATURE OF THE UPPER PART OF THE POPLITEAL (A) AND OF THE POSTERIOR TIBIAL ARTERIES (B, C, AND D).

E, Site for introduction of knife in tenotomy of tibialis posticus; F, ditto for tendo Achillis.

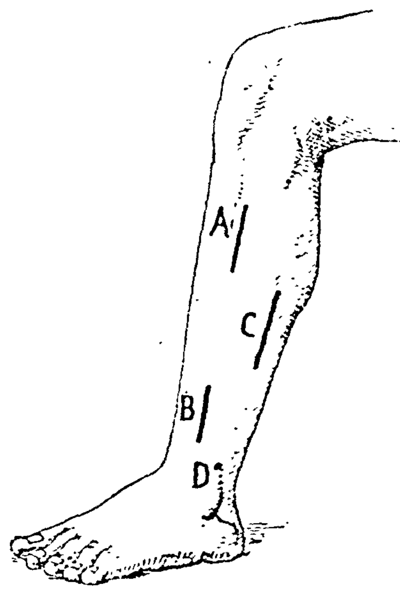


FIG. 144.—INCISIONS FOR LIGATURE OF ANTERIOR TIBIAL (A AND B) AND PERONEAL (C) ARTERIES.

D. Site for introduction of knife in tenotomy of peronei.

centre of the popliteal space to a point a finger's breadth behind the internal malleolus.

1. *In the Middle of the Calf.*—The leg is placed on its outer side and flexed, and an incision 4 inches long is made a finger's breadth behind the inner border of the tibia (Fig. 143, B), dividing the skin and subcutaneous tissues, the long saphenous vein and nerve being drawn aside if necessary. The tibial origin of the soleus is thus exposed, and incised directly towards the tibia, until the fibrous aponeurosis on its deeper surface is met with. This having been cut through, the muscle is drawn backwards with the retractor, and the vessels, ensheathed in a deep layer of fascia, are seen lying on the tibialis posticus, and with the posterior tibial nerve to the outer side.

23

2. *In the Lower Third of the Leg.*—An incision is made midway between the tendo Achillis and inner border of the tibia (Fig. 143, C). The skin and fasciæ, including the upper part of the internal annular ligament, are divided, and the vessels seen lying on the flexor longus digitorum, with the nerve behind and to the outer side.

3. *Behind the Malleolus.*—An incision is made about a finger's breadth from the malleolus, curving round its lower border (Fig. 143, D). The deep fascia (or, as it is here termed, the internal annular ligament) is divided over the vessels between the tendons of the flexor longus digitorum and flexor proprius hallucis, and the artery is then readily cleared and ligatured. The sheaths of the tendons should not be opened.

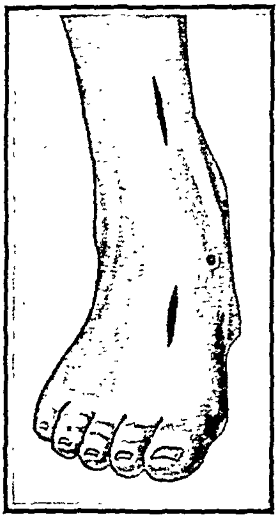


FIG. 145.—INCISIONS FOR LIGATURE OF LOWER PART OF ANTERIOR TIBIAL AND DORSALIS PEDIS ARTERIES; ALSO SITE FOR PERFORMING TENOTOMY OF TIBIALIS ANTICUS.

The **Anterior Tibial Artery** is found along a line stretching from a point midway between the outer tuberosity of the tibia and the head of the fibula above to the central point between the two malleoli below. It may be tied in three situations.

1. *In the Upper Third of the Leg.*—An incision is made exactly in the line of the artery (Fig. 144, A), and the deep fascia incised. The intermuscular space between the tibialis anticus and the extensor communis digitorum is opened. The vessel lies between these muscles upon the interosseous membrane, the anterior tibial nerve being to the outer side.

2. *In the Middle of the Leg* (Fig. 144, B).—The same intermuscular space is opened, being indicated here by a definite white line, due to a slight subfascial deposit of fat. The vessels lie between the tibialis anticus and the deeply-placed extensor proprius hallucis, the nerve usually lying on the artery and needing to be drawn aside.

3. *In the Lower Third of the Leg.*—An incision is made in the line of the artery, reaching npwards for 2 inches from a point just above the ankle (Fig. 145). The deep fascia and upper part of the annular ligament are divided, and the vessel is found between the tendons of the tibialis anticus and of the extensor proprius hallucis, the nerve lying to the outer side.

The **Dorsalis Pedis Artery** extends from the centre of the line between the two malleoli to the interval between the bases of the first two metatarsal bones. An incision is made in this direction (Fig. 145), the deep fascia opened, and the artery found lying between the extensor proprius hallucis, which has now crossed and is internal to the vessel, and the innermost slip of the extensor brevis digitorum. It is not always easy to find, and for practical purposes the best plan would be to divide the vessel by an incision extending to the bones, and then pick up and tie the bleeding ends.

The **Peroneal Artery** can be reached through an incision along the posterior border of the centre of the fibula, the leg being laid on its inner side (Fig. 144, C). The outer edge of the soleus is defined and drawn inwards, the lower fibres of attachment to the fibula being divided if necessary. The flexor longus hallucis is thereby exposed, and incised in such a manner as to allow the surgeon to reach the postero-internal border of the fibula; the artery is then readily found lying in an osseo-aponeurotic canal.

CHAPTER XIII.

AFFECTIONS OF THE VEINS—ANGIOMATA.

Venous Thrombosis.

By **Thrombosis** is meant intravascular coagulation in any part of the circulatory system. Normally, the blood remains in a fluid condition, owing to some interaction between it and the vessel walls. Any factor producing a disturbance of this normal equilibrium may determine thrombosis, and any part of the vascular tract may be affected by it, whether the heart, arteries, veins, or capillaries; but it is in the veins that it occurs most frequently.

Causes.—(1) *Changes in the vessel walls*, as a result of which the integrity of the endothelium is disturbed, *e.g.* injury (either division, rupture, puncture, compression, or contusion), inflammation or degeneration (as in varicose veins).

(2) *Changes in the constitution of the blood* whereby its coagulability is increased. In clinical work this is brought about most frequently by infective conditions, which lead to an excess of toxins in the blood. Hæmorrhage up to half of the whole amount in the body also increases its coagulability, but excess of leucocytes, as in leukæmia, has the opposite effect.

(3) *Diminished rate of the blood-stream* predisposes to thrombosis if some other condition is present to determine it. Lister showed years ago that blood can remain fluid for a long time if confined in a tube formed of a suitable length of healthy vein wall; but when either of the preceding factors is present, a retardation of the blood-stream materially assists in causing coagulation. Thus, when a vein is pressed upon by a tumour, the obstruction to the blood-flow produces a clot at the spot where the nutrition of the wall is interfered with. After fevers, such as typhoid, where the character of the blood is somewhat altered and the action of the heart weakened by changes in the myocardium, the defective *vis a tergo* causes a retardation of the flow in the veins, and coagulation is probably determined by some slight injury or pressure which is not noticed by the patient.

The **Character** of the clot varies with its rate of formation. If developed slowly, the so-called white thrombus is met with, consisting merely of layers of fibrin, similar to that formed in an aneurism. If the process is more rapid, a certain number of red corpuscles are entangled in the meshes of the clot; sudden coagulation produces the ordinary red thrombus, which at first is not adherent to the wall, but becomes so later on, especially at its base.

The **Effects** of thrombosis may be considered under the following headings: local, distal, and proximal.

Locally.—(*a*) The clot may be organized into connective tissues, a fibrous cord replacing the vessel in the same way as was described for arterial thrombosis (p. 314). Three weeks is about the shortest period to allow for the safe fixation of the clot within the vessel. (*b*) The lumen of the vein may be re-established by the fixation of the thrombus to one side of the vein wall, or by canalization of the clot or of the fibrous cicatrix replacing it, owing to the dilatation of the vessels contained within. (*c*) The clot may shrink or become loosened in an ampulla of a varicose vein, forming a fibrinous mass, which is subsequently infiltrated with calcareous particles constituting a vein-stone or *Phlebolith.* (*d*) Suppuration may occur in and around the clot as a result of its bacterial content.

A localized abscess may follow, or the pus may spread widely along the course of the vein (periphlebitis). Pyæmia is likely to develop, but this may be hindered for a time by the formation of a cap of healthy red clot, which covers over and protects the infected portion.

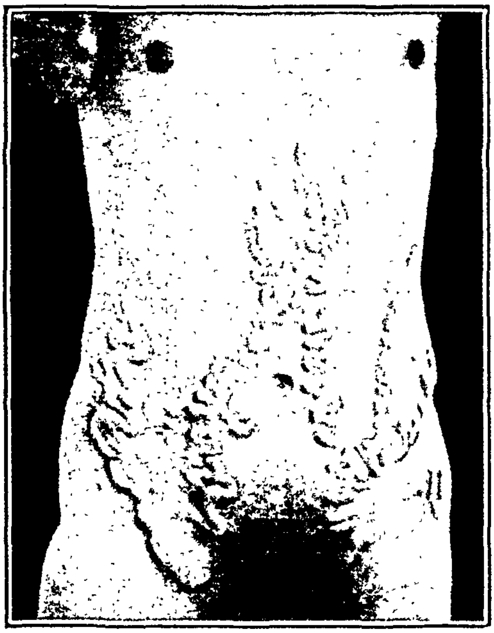


Fig. 146.—Varicose Condition of the Veins of the Abdominal Wall Secondary to Permanent Obstruction of the Inferior Vena Cava.

Distally.—The area drained by the affected vein becomes congested and œdematous, if sufficient collateral circulation does not exist, unless it is kept well raised and supported. In favourable cases collateral circulation is soon established by the opening up of other venous channels, which after a time may become varicose, and, if situated superficially, are often very obvious. Thus, if the external iliac vein is occluded above Poupart's ligament, a greatly increased amount of blood will be carried by the internal saphena vein, and some of it will find its way *via* the superficial epigastric and pudic veins across the middle line to the internal saphena of the opposite side. These branches become dilated and varicose, and the inverted ∧ of the two superficial epigastric veins is very characteristic. If the inferior vena cava is obstructed, the mammary and epigastric veins become dilated and tortuous, the latter standing out prominently on the anterior abdominal wall (Fig. 146).

Proximally, the process may gradually extend upwards, and finally involve larger and more important trunks than that in which it originated. Moreover, a portion of a thrombus may be detached as an *Embolus* (Fig. 147). If the clot is undergoing molecular disintegration, and only minute portions are set free, they are filtered off

by the lungs or kidneys, and no symptoms need be caused. If, however, a large portion is detached, urgent dyspnœa and even death occur from obstruction to the pulmonary vessels and subsequent arrest of the circulation. If the clot becomes infected, and fragments conveying organisms are carried into the circulation, pyæmia is the result, preceded, however, in the portal area by pylephlebitis, *i.e.* suppurative phlebitis of the portal trunk in the liver.

Femoral Thrombosis is of considerable interest to the surgeon, as it is not uncommon after operations on the pelvic viscera, *e.g.* the uterus or prostate, and is frequently seen as a complication of a suppurative appendicitis, the thrombosis spreading from the divided veins in the parietal incision, or *via* venous communications in the meso-appendix, or possibly as a result of the direct involvement of the right iliac vein in the inflammatory trouble. The condition is not an unfrequent complication of parturition, and is then due to extension of the clotting from the uterine veins (*phlegmasia alba dolens*). It may develop in the course of typhoid fever, or follow any condition or operation which depresses the patient's vitality and keeps him bedridden with the legs quiet.

It is most frequently seen in the left leg, and according to its varied cause the clotting may start in the pelvic veins and spread upwards to the common iliac vein; or it may commence in branches of the external iliac, and so progress to the main trunk; or the femoral vein, usually about its junction with the saphena, may be first involved. In all cases the thrombosis is likely to spread down the femoral vein for some distance, and up the common iliac trunk, sometimes involving the bifurcation of the vena cava, and so extending to the opposite side of the body. It is difficult to give quite a satisfactory explanation of the more frequent involvement of the left side of the body, but probably it is due to unnecessary limitations of the movements of the legs, together with anatomical differences in the arrangements of the valves in the veins to the detriment of the circulation on the left side; or perhaps to the pressure on the iliac vein of an overloaded or long sigmoid colon hanging over the brim into the true pelvis.

The **Clinical Signs** and **Treatment** are as for Phlebitis (p. 360).

Embolism.

An **Embolus** is the term applied to any foreign body which travels for a greater or less distance in the blood-vessels until it becomes lodged within them and causes obstruction. There are four main varieties of embolus: (*a*) **Simple Emboli,** *e.g.* blood-clot, granulations or fibrinous vegetations from the cardiac valves after acute endocarditis, atheromatous plates, air-bubbles, fat globules, etc. (*b*) **Infective Emboli** consist of either zooglœa, masses of bacteria, or disintegrated portions of blood-clot carrying micro-organisms, and are the cause of the abscesses in pyæmia. (*c*) **Malignant Emboli** are formed by portions of some malignant growth, from which the various

secondary deposits originate; these are met with more frequently in the sarcomas than in the carcinomas. (*d*) **Parasitic Emboli** also occur, such as the ova and scolices of the *Tænia ecchinococcus* and the *Filaria sanguinis hominis*.

Emboli may be detached from the heart, veins, or arteries, although necessarily they are never arrested in a systemic vein, but only in the arteries or portal vein. They are of all sizes, and the character of the resulting symptoms depends much on this. A large embolus started in a peripheral vein lodges in one of the branches of the pulmonary artery, and may cause instant death; a smaller one is arrested in one of the smaller arteries of the lung and may do but little harm, whilst minute ones may possibly pass through the pulmonary capillaries to the left side of the heart, and subsequently become impacted in the systemic vessels.

Effects of an Embolus.—The **Local** effects of the lodgment of a simple embolus consist, firstly, in the deposit of fibrin upon it, rendering the obstruction complete, if this is not already the case; organization of the thrombus usually follows, although occasionally it may disintegrate and disappear. The local effects of infective, malignant, and parasitic emboli are dealt with elsewhere.

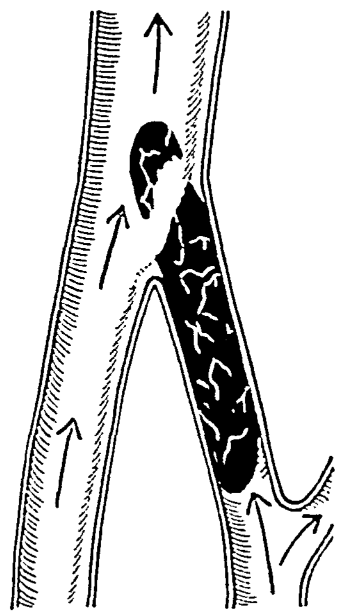


FIG. 147.—THROMBUS AND EMBOLUS.

The **Distal** effects of embolic obstruction depend entirely on the relation of the vessel blocked to the surrounding circulation.

(1) Should the embolus be lodged in an artery which gives off anastomotic branches below the point of obstruction, or if the capillary anastomosis is abundant, a **transient anæmia** is all that occurs in most cases. If the artery is small, or goes to unimportant structures, no symptoms need arise from this; but if the vessel is large, or supplies delicate and important tissues, serious results may follow even a temporary arrest of the circulation; thus, embolus of the central artery of the retina always causes permanent blindness, although the retina still lives.

(2) Should the embolus block what is called a 'terminal artery,' *i.e.* one with no anastomosis between the embolus and the terminal capillaries, or a vessel with insufficient collateral circulation, the obstruction will lead to **death** of, at any rate, a portion of the anæmic region, *e.g.* gangrene in a limb, or white or yellow softening in the brain. In an organ such as the kidney or spleen, the result of embolic obstruction to one of the terminal arteries is the development of an infarct, *i.e.* a wedge-shaped area of tissue with the blocked artery at its apex becomes devitalized, and in consequence looks white and feels firmer than the surrounding parts. The tissues cannot be properly stained for microscopic purposes. Sometimes the anæmic area becomes engorged with blood to such an extent as to lead to extravasation, and

a firm, solid patch of a dark red colour results, known as a **hæmorrhagic infarct.** Whatever its appearance, the **infarct** is subsequently invaded by granulation tissue developed from the surrounding healthy parts, and this finally results in the formation of a depressed cicatrix containing, perhaps, a few hæmatoidin crystals. The conditions necessary for the production of an infarct are met with in the lungs, spleen, kidney, and brain; in the liver the anastomosis is generally too free to allow of its formation, although it has been known to occur.

Effects of the Lodgment of Emboli in Various Organs.—In the **Brain,** the middle cerebral artery is most commonly blocked, resulting in immediate hemiplegia, which may be almost entirely recovered from, but commonly leaves some impairment of function. In children the symptoms are less marked, but aneurism of the affected vessel occasionally follows. In the **Central Artery of the Retina,** sudden, total, and irremediable blindness is produced; the branches of the vessel are seen to be almost empty, the retina becomes œdematous, the macula alone retaining its normal colour, appearing as a cherry-red spot, contrasting markedly with the pallid œdematous tissues around. In the **Lung,** fatal results supervene from obstruction to the main pulmonary artery; attempts have been made to save life by opening the chest, incising the pulmonary artery, and scraping or pulling out the clot, and subsequently suturing the vessel. It is obvious that such a proceeding is not often likely to be feasible, but it has been successfully done. If one of the smaller branches is blocked, a certain amount of pain and dyspnœa is produced, followed by the formation of an infarct, as indicated by blood-stained sputum, dulness, bronchial breathing, and bronchophony. In the **Liver,** an embolus of the hepatic artery causes sudden hypochondriac pain, and perhaps a temporary glycosuria. The portal vein and its branches are not unfrequently obstructed by emboli, which, being usually of an infected nature, give rise to pyæmic symptoms (pylephlebitis). In the **Spleen,** a sudden pain in the left hypochondrium is experienced, the organ becomes enlarged, and a considerable rise of temperature may follow. In the **Kidney,** sudden pain in the loin and a temporary hæmaturia constitute the main symptoms. In the **Intestine,** localized ulceration or extensive gangrene is likely to follow, according to the size of the vessel obstructed. In the **Limbs,** the emboli usually lodge at the bifurcations of main vessels, often saddling across the fork, and blocking both branches. Sudden pain is felt at the spot, shooting downwards, and either recovery or gangrene ensues (p. 98).

Phlebitis.

Phlebitis, or inflammation of the vein wall, arises from a variety of causes, and is not uncommon in surgical practice. The following forms are described:

1. **Simple Phlebitis,** in which a more or less *localized* inflammation of the wall of a vein is attended by thrombosis, which extends for a variable distance up and down the vessel. (*a*) It may arise from *injury*, either subcutaneous or open, or from the continued pressure

and irritation of a tumour or aneurism; (*b*) it may be gouty or rheumatic in nature, attacking the larger veins of the lower extremity, or vessels which have been long subject to varix. (*c*) It may follow primary thrombosis, either in the main trunk or in a varicose peripheral vein; or (*d*) it may be induced by inflammation of the tissues around the vein (*periphlebitis*), usually of bacterial origin. In the last case the bacteria gradually spread through the vein wall, and finally invade the clot.

2. **Infective Phlebitis** is a much more serious condition, inasmuch as the thrombus resulting therefrom always contains micro-organisms, and the disease is often of the *spreading* type. It arises (*a*) in traumatic cases where asepsis has not been maintained, the organisms invading the clot which lies in the open mouth of the vein; or (*b*) as a result of infective periphlebitis in wounds, or in infective inflammation of bones, such as when a suppurative mastoiditis leads to thrombosis of the lateral sinus; and (*c*) by auto-infection of the clot present in simple phlebitis, as, *e.g.*, in varicose veins.

Morbid Anatomy.—The walls of the vein are congested and thickened, and the endothelial lining is hypertrophied. The thrombus, if aseptic, early becomes adherent to the vein wall and organized, or is absorbed; if infected, it becomes soft and pultaceous, resembling dirty-looking pus; a localized abscess may form, and the suppuration may extend for some distance along and around the vein.

The **Symptoms** of inflammation of a **superficial** vein are sufficiently obvious. The vessel becomes swollen, hard, and painful, with localized enlargements or knobs corresponding to the valves or to the pouches in varicose veins. The skin over them is dusky and congested, and there may be some œdema of the region from which the blood flowing in the vein is gathered; this, however, rarely amounts to much, since the collateral circulation is always abundant. The temperature is usually raised, and the patient feels ill. If suppuration occurs, the signs of a localized abscess are noted, and perhaps pyæmic manifestations supervene.

When the **deeper** veins are involved, it may be impossible to detect them on palpation, although a blocked common femoral can usually be felt; but acute deeply-seated pain over the vein and well-marked fever are characteristic evidences of what has occurred. Œdema of a more or less solid character develops, although if the limb is maintained in the horizontal position throughout the attack this need not occur. Obliteration of the vessel and any of the local, distal, or general processes detailed as characteristic of thrombosis (p. 356) may result.

The onset of an **infective periphlebitis** is marked by fever and perhaps rigors, whilst the local signs are due to rapid extension of a suppurative inflammation along the vein and its branches, so that a large tract of tissue is very quickly invaded, and diffuse suppuration follows. The presence of pyæmia is indicated by a repetition of rigors, and the development of secondary abscesses.

Treatment.—In the **simple** variety the limb is kept at rest to limit inflammation and prevent the detachment of emboli, and also elevated to assist venous return. Locally, belladonna fomentations may be

applied, or the parts may be painted with glycerine and extract of belladonna; the limb is then lightly bandaged over a thick layer of cotton-wool. The intravenous injection of 5 to 10 ounces of a 0·5 per cent. solution of sodium citrate in normal salt solution appears to cause a rapid cessation of pain and tenderness, whilst it stays the spread of the trouble and hastens the disappearance of the œdema. The injection is sometimes followed by a rigor, but that does not seem to do any harm. The patient should be kept on an unstimulating though nutritious diet, and the general health attended to. When every sign of inflammation has subsided, and sufficient time has been allowed for the absorption or organization of the clot (three weeks as an absolute minimum, six weeks for choice), massage may be commenced, to assist in the removal of œdema and local thickening, and an elastic bandage is usually serviceable in restoring the circulation.

Infective phlebitis is treated in a similar fashion until suppuration occurs, and then the pus must be evacuated, and it is sometimes remarkable to note how quickly the process quiets down when once drainage is effected. A **spreading periphlebitis** will often involve an extensive area, but the process must be followed up ruthlessly by the knife and the parts laid open. The wounds thus made should be lightly packed and allowed to granulate; at the same time the limb is raised, and kept absolutely quiet. Should pyæmic phenomena develop, it may be necessary to place a ligature between the disintegrating clot and the heart, and to scrape or wash away the infective material; thus, in thrombosis of the lateral sinus, following suppuration in the middle ear, the internal jugular vein should be ligatured, the lateral sinus opened, and the clot removed. Of course, such treatment is only feasible in cases where a single trunk is affected. When the process involves the veins of a limb, and cannot be stopped by either of these plans of treatment, the question of amputation may have to be raised.

Varicose Veins, or Varix.

A vein is said to be in a condition of varix when it has become dilated, permanently lengthened, and more or less tortuous. The superficial veins of the leg, especially the internal and external saphena, are those most commonly affected; the spermatic veins are often in a similar condition, constituting what is known as a varicocele, whilst piles are primarily due to varicosity of the hæmorrhoidal plexus. We shall here only deal with the first of these three manifestations.

Causes.—Varix is possibly due to some inherited weakness of the venous wall, or irregularity in the arrangement of the valves, or peculiarity in the lower fascial border of the saphenous opening, though these may produce no ill-effect until some exciting cause comes into action. The condition sometimes appears quite early in life, and often involves the same vein in different members of a family.

The condition also results from persistent distension of a vein, as by wearing tight garters, or by the pressure of a pregnant or displaced uterus, or of a pelvic tumour; or from prolonged standing, which

may cause tension of the deep fascia of the thigh, and this may lead to constriction of the veins at the openings through which they pass to deeper parts, *e.g.* the saphenous opening with its sharply defined falciform border. Valvular incompetence from the giving way of valves in the upper part of the saphena as a result of severe exertions, *e.g.* in athletics, may lead to varix, as the effect of the gradually increasing weight of the superincumbent column of blood. Occlusion of the deeper veins, *e.g.* of the common femoral or vena cava (p. 357), leads to distension and varix of the superficial; thus thrombosis of the venæ comites of the posterior tibial, due to muscular strains, may be followed by varix of the internal saphena or some of its branches below the knee. An abnormal communication between an artery and vein also results in varix from the inability of the latter to withstand arterial blood-pressure (*vide* Aneurismal Varix, p. 317). The tendency to varix increases with age till the middle period of life is reached, and is favoured by relaxation of the system resulting from sedentary habits.

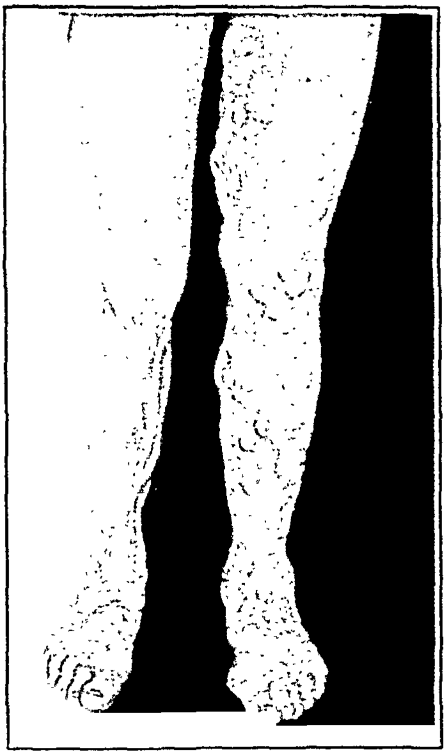


FIG. 148.—VARIX OF INTERNAL SAPHENA VEINS.

Morbid Anatomy.—To the naked eye a varicose vein in an early stage appears thickened, distended, and tortuous; the walls are so thick that the vein when cut across does not collapse, but presents a gaping mouth, like an artery; the valves atrophy, and are functionally useless. After a time the walls become further stretched and irregularly expanded, forming here and there cyst-like dilatations, which are very obvious under the attenuated skin, to which they are often adherent. Microscopically, the change consists in a transformation of the normal structures of the vein wall into fibro-cicatricial tissue. The tunica media is mainly affected, most of the muscular fibres disappearing, whilst the tunica intima is but little changed, and the adventitia thickened. In the pouches the middle coat is atrophied, and, indeed, is often completely absent.

Clinical History.—The enlarged veins are seen ramifying under the skin with a more or less tortuous and serpentine course (Fig. 148), and they often feel thickened. One or more veins may be affected, and the tortuosity may be at parts so marked as to constitute large clusters of dilated vessels, which look bluish under the thin and stretched integument. In other cases a single vein is enlarged, and stands out prominently under the skin; or perhaps one or more cyst-like pouches

develop in connection with these. The upper end of the internal saphena is sometimes dilated so as to form a large pouch, in which a marked thrill is felt when the patient coughs, thereby simulating a femoral hernia. In other cases, although this portion of the vein is not dilated, yet its valves are incompetent, and the thrill produced by coughing can be felt even below the knee if that portion of the vein is dilated.

The **Effects** of varicose veins are very varied. The limb often feels heavy and tired; forcible exertion may cause a sensation of tension, and after standing or exercise there is usually some œdema of the ankle. The capillaries in the papillæ often become dilated, appearing as minute reddish puncta, which subsequently run together and form brownish patches of pigmentation. Eczema is induced by the irritation of rough and coarse trousers or dirt, often terminating in actual ulceration. Any lesion, such as a scratch or abrasion, instead of healing readily under a scab, tends to spread and form an ulcer. Injury to the vein may lead to thrombosis and subsequent cure, but coagulation sometimes occurs spontaneously in cysts or acute kinks, especially in gouty subjects. The clot may subsequently shrink and form a small fibrinous or calcareous mass, known as a 'phlebolith,' but sometimes the thrombosis spreads into deeper or larger veins, and then

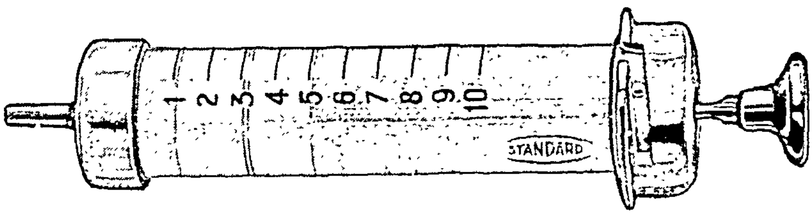


FIG. 149.—SYRINGE USED FOR INJECTING VARICOSE VEINS.

fragments of clot may be detached as emboli. Occasionally the dilated pouch of a varicose vein gives way, and an alarming rush of blood results; the same may follow the extension of ulceration through the vein wall. The blood under these circumstances is derived, not only from the lower, but also from the upper end; and if the valves have become incompetent, a column of blood extending from the right auricle is thus tapped near its lower end, and, unless prompt precautions are taken, the patient's life may be lost.

The **Treatment** of varicose veins may be described as palliative or radical.

Palliative Treatment consists in removing any source of obstruction in the shape of tight garters, in limiting the amount of standing, in moderate massage, together with the application of either an elastic stocking or an indiarubber bandage. The bowels should be regulated, and the general health attended to. Eczema may be treated by the application of soothing and drying ointments, *e.g.* ung. zinci benzoatis; or if the skin is chronically infiltrated and thickened, by the use of weak tarry applications, *e.g.* ol. Rusci (1 part to 4 of vaseline), or of ichthyol (5 or 10 per cent. in vaseline). Varicose ulcers are suitably treated (p. 83), but repair is often delayed till the veins have been dealt with by operation.

Operative Treatment may be directed either to the obliteration of the distended veins or to their complete removal.

1. The *obliteration* of varicose veins without a cutting operation was the aim of surgeons in pre-antiseptic days when the fear of pyæmia was ever present. Of late a similar object has been sought by modern methods so as to avoid the discomfort, expense, and manifold objections to extensive operations which are not always successful. It has been found that the injection into the lumen of various more or less irritating fluids, whose absorption into the blood-stream is not harmful, is followed by a plastic thrombophlebitis, limited in extent to the neighbourhood of the injection, and without pain or the necessity for prolonged rest, and thereby obliteration is secured. The thrombi are very adherent, and thus there appears to be no risk of embolus. A solution of salicylate of soda, 30 or 40 per cent., is very suitable, but solutions of quinine or biniodide of mercury have also been employed. The latest solution to be advocated is sodium morrhuate; it has no toxicity, and amounts up to 10 or 12 c.c. of a 10 per cent. solution have been given at one time. In most cases 2 to 5 c.c. is the correct dose for each injection. A 10 c.c. special syringe should be used (Fig. 149), fitted with a needle 1 inch in length with a short bevel. The skin over the site is cleansed with ether, and the needle introduced into the lowest portion of the varicose vein. That the needle is actually in the vein is verified by drawing out the piston and observing blood flow back into the syringe, after which 2 or 5 c.c. of the solution are injected, according to the size of the vein. The greatest care must be taken to prevent any escape of the fluid into the tissues, as necrosis may be thereby determined (Fig. 150). A small dressing is applied and the patient is allowed to return to his work. In a day or two the vein wall is sensitive and a little thickened, but obliteration usually follows without trouble. Possibly 3 or 4 inches of the vein are occluded as the result of a single injection. This procedure may be repeated as often as is considered necessary in different portions of the limb.

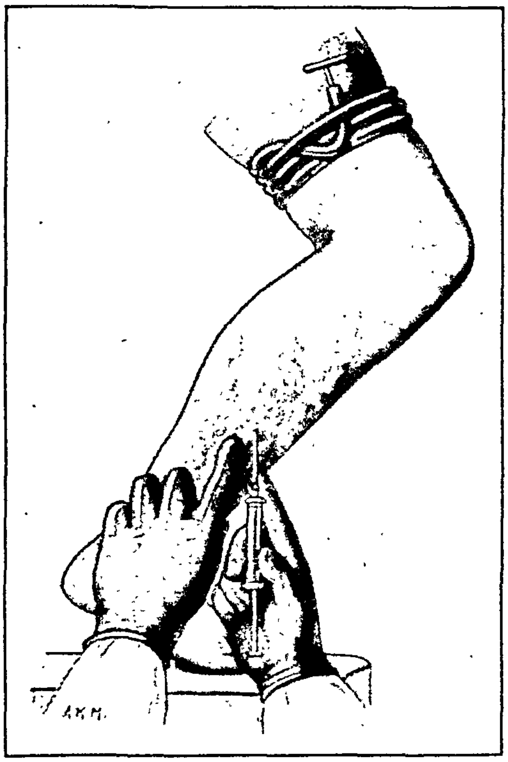


FIG. 150.—INJECTION OF VARICOSE VEINS WITH SODIUM MORRHUATE FROM A LARGE SYRINGE.

If a varicose ulcer is present it should be treated by means of an elastoplast bandage (Figs. 151 and 152); see also p. 84.

2. *Excision* of varicose veins, although practised extensively in the past, has been entirely replaced by the injection treatment.

Inflamed Varicose Veins are not unfrequent, and may result in a natural cure of the condition. The symptoms are those of a superficial phlebitis, and the treatment indicated for that condition should be followed.

Hæmorrhage from a Ruptured Vein needs prompt and decisive treatment. The bleeding spot should be controlled by digital compression, and the patient laid on the back with the limb elevated, until either a pad of antiseptic dressing can be applied to the wound or a handkerchief or bandage secured over it.

Venesection has largely fallen into disuse of late years, but is still occasionally employed with benefit in the following conditions: (*a*) When a patient is becoming cyanosed, and asphyxia is threatening as a result of pulmonary engorgement from mitral incompetence; (*b*) when some accident involving the chest wall and lungs diminishes

FIG. 151.—LARGE VARICOSE ULCER OF MANY YEARS' DURATION BEFORE TREATMENT

FIG. 152.—SAME CASE AFTER TREATMENT WITH ELASTOPLAST BANDAGE.

the blood-aërating surface so that it cannot deal with the blood reaching it through the right side of the heart, which hence becomes enormously distended, and threatens to stop in a condition of diastole; or (*c*) where inflammation of the brain is pending, and the pulse is hard and full; or (*d*) in a few inflammatory states in strong, full-blooded individuals where the pulse-tension is high.

The median basilic vein at the bend of the elbow is that usually opened, since it is larger than the median cephalic, though placed more directly over the brachial artery, from which it is only separated by the bicipital fascia.

Intravenous Medication.—So many drugs are now administered by the intravenous route, especially the salvarsan group, that it is essential for medical practitioners to familiarize themselves with this means of treatment. An evening spent in a venereal clinic will be more profitable than pages of description, but it is sufficient here to suggest the necessity for absolute sterilization of the appliances employed and of the skin over the site of injection. One of the veins

of the forearm is selected and caused to become distended by the application of a bandage above, whilst the fist is alternately clenched and opened. The needle is passed through the skin alongside the vein for a short distance and then driven through the wall, thus making an oblique puncture. The bandage is at once released, and the injection then made. Of course, care is taken to avoid the risk of injecting air. No dressing need be applied to the minute puncture, but it may advisedly be dabbed over with tincture of iodine.

Angiomata.

Tumours of blood-vessels present varying appearances according to the situation and the character of the vessels of which they are composed. They are frequently of congenital origin or developed soon after birth. They involve most commonly the skin or mucous membrane, together with the underlying tissues, and are then known as **nævi**; but they are occasionally acquired and develop in deeper organs, such as the liver. According to their structure they are divided into three main groups: the simple or capillary nævus, the cavernous nævus, and the plexiform angioma.

1. The simple or **Capillary Nævus** (mother's mark) is exceedingly common, and consists of a mass of dilated capillaries held together by a small amount of connective tissue. It is usually located in the skin, but may also involve the subcutaneous tissues; the tubular form of the constituent vessels always remains. It occurs in the form of a slightly raised flattened mass, bright red or purple in colour, according to the relative amount of arterial or venous blood present, and with occasionally a somewhat irregular or nodulated surface, in which larger vessels may be seen ramifying. Several such growths may be present in the same individual, and they are usually quite small, rarely exceeding an inch or two in diameter; they are present at birth or appear soon after. The head and face are the parts most commonly affected. Angiomata of the mucous membranes are often a source of considerable danger and trouble from hæmorrhage, especially in the bladder and nose.

A more superficial variety known as the **port-wine stain** often extends widely over the face and neck, and is somewhat dusky in colour; this condition consists merely of a network of fine vessels, and does not project above the surface.

Occasionally a nævoid development may be observed having a linear distribution down the long axis of a limb, or running transversely half round the trunk, and limited almost exactly by the middle line; this condition is known as *nævus unius lateris*. It may consist purely of a vascular manifestation, or the skin may be hypertrophied and covered with small soft papillary excrescences.

The term **Spider Nævus** (*N. araneus*) is applied to a small angioma, which develops usually in young people, and generally on the face, from which radiate a considerable series of fine red lines. When irritated they bleed easily, but are readily cured by the application of carbonic acid snow or a pointed cautery.

It is not uncommon in middle-aged people to find a number of small red spots on the trunk, which sometimes persist for a while and then disappear. These **telangiectases** (or *De Morgan spots*) consist of dilated capillaries, and are possibly degenerative in origin.

Left to themselves, simple nævi may remain unchanged, or disappear; more often they increase in size more or less rapidly, and may invade surrounding tissues, requiring active treatment in order to check their progress. Sometimes they persist unaltered till middle life, and then may increase rapidly, giving rise to a considerable vascular tumour, purple in colour, and occasionally becoming prominent and pendulous. Such a tumour is soft and easily compressible, being in reality a cavernous angioma; it may ulcerate, and profuse hæmorrhage may result.

Treatment is usually simple in the extreme. Small superficial nævi can be completely cured by some form of cauterization, the best results being obtained by the use of carbonic acid snow. Appliances for the supply and employment of this agent are obtainable from instrument makers. In exposed situations electrolysis may be the best plan to adopt, but excision will often give a good result. Radium may be used in some cases.

2. A **Cavernous Nævus** (Fig. 153) most commonly involves the subcutaneous or submucous tissues, but is sometimes associated with a superficial nævus. It consists of dilated spaces where the tubular form of the constituent vessels is lost, the arteries often opening directly into thin-walled cavities lined with endothelium without the intervention of capillaries. The tumour thus produced is a more or less prominent swelling, soft to the touch, and easily compressible, but refilling when the pressure is removed. There is usually no pulsation or bruit, although both may be present, and the mass may be definitely circumscribed, or more or less diffuse. If subcutaneous, the skin over it is somewhat bluish in colour; when the skin is involved, the mass presents a dusky red appearance. Occasionally these growths undergo spontaneous cure from inflammation and thrombosis, and cysts are sometimes found in the centre of a nævoid mass, indicating that a partial attempt at this process has occurred. A similar condition arises in the viscera, especially the liver, and it is not difficult in certain suitable cases to demonstrate that it has been formed by a dilation of the capillaries between the lobules, the liver substance meanwhile disappearing by a process of simple atrophy.

The **Treatment** is by no means as simple as in the former variety. The following plans may be mentioned:

(1) Excision of the growth should always be adopted where practicable. The bleeding is never great, even if the nævoid tissue is encroached upon by the knife, and only a few vessels will need to be tied. Circular growths should be removed by crescentic incisions, and a little undercutting will usually enable the edges to be approximated.

(2) Where excision is impossible, **diathermy cautery** should be employed. It consists in the passage of an electric current through the mass, producing chemical and physical changes in the contained blood.

3. **Plexiform Angioma.**—This term is now generally applied to an angioma in which the arterial element predominates, although veins and capillaries are also present. The growth is usually seen in young people, and affects most frequently the scalp, especially the temporal or occipital regions. A tumour is produced which is soft and compressible, pulsating forcibly, and with a marked bruit (**cirsoid aneurism,** *q.v.*). It usually consists of large obvious dilated pouches, the skin over which is thinned, and may give rise to serious hæmorrhage, or grave infective troubles. Sometimes the growth consists of smaller arteries, and partakes more of the character of an arterial nævus,

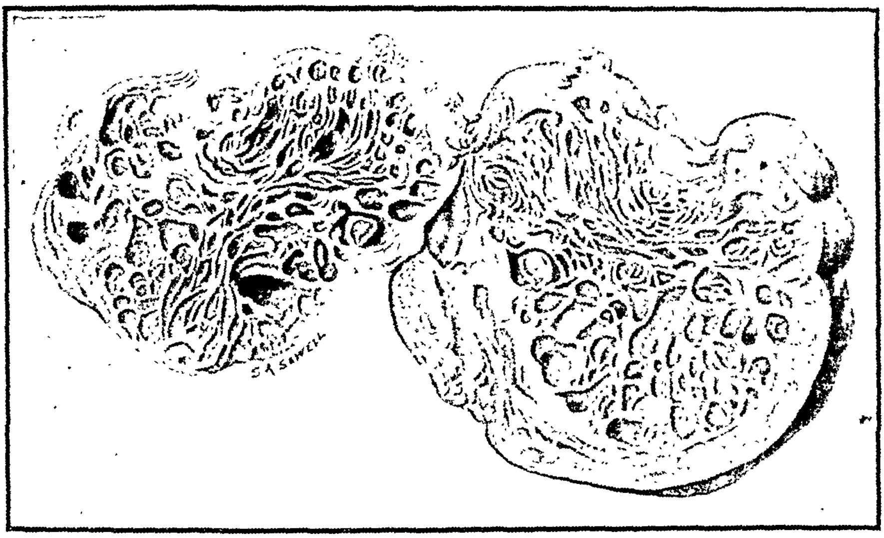


FIG. 153.—SECTION OF CAVERNOUS ANGIOMA. (ROYAL COLLEGE OF SURGEONS MUSEUM.)

In one or two of the cavernous spaces thrombi more or less adherent can be seen.

but the tubular condition of the vessels is often lost. This variety (**aneurism by anastomosis**) is found in the interior of bones, in some forms of pulsating exophthalmos, and in the scalp.

A **Nævo-Lipoma** is the name given to a somewhat rare tumour, in which a fatty element is blended with nævoid tissue. It is usually of congenital origin, or at any rate appears early in life. It gives rise to a swelling, lobulated and doughy, like a fatty tumour, although it is often rather denser in texture than the ordinary lipoma. It may be possible to reduce its size by compression, but no thrill or pulsation can be detected; a few dilated veins or capillaries are often seen on the surface. The only treatment is excision.

CHAPTER XIV.

DISEASES OF THE LYMPHATICS.

Rupture or Division of the Thoracic Duct may occur as a result of a penetrating or bullet wound of the neck, or during operations in the supraclavicular fossa. The main trunk has also been torn in a fracture of the spine, and the lymph has escaped into the pleural cavity. Wounds near the outflow into the junction of the jugular and subclavian veins usually involve one or more of the several branches into which the main trunk divides before opening into the venous system; lymph or chyle escapes, but if the divided vessel is tied, no further trouble arises as a rule. Failing ligature, the wound should be packed with gauze, and the flow generally ceases after a while. Should this not occur, an attempt must be made to anastomose the divided end of the duct with one of the deep veins, for a persistent and excessive loss of lymph means the exhaustion of the patient.

In a few cases the opening of the thoracic duct has been *obstructed* or compressed, leading to such backward tension that the receptaculum chyli has ruptured and the peritoneal and pleural cavities have been flooded with a serous or chylous exudation.

Acute Lymphangitis, or Inflammation of the Lymphatic Vessels, ensues almost invariably from the absorption and passage along the lymphatics leading from an infected wound of bacteria (usually streptococci) and toxins, which give rise to inflammation of the lymphatic vessels involved and of the tissues around them, and this may even run on to suppuration. The walls of the lymphatics become hyperæmic and infiltrated, and the tissues around are inflamed. The lymph coagulates in the vessels, forming a pinkish clot. This process is usually limited by the nearest lymphatic glands, which arrest and filter off the toxic products, with or without the occurrence of suppuration; but, in spite of this, a general infection of the system occasionally results.

Clinical Signs.—The causative wound may be obviously infected, or is possibly very slight and covered by a dry scab. The characteristic appearance is that of fine red lines or streaks following the course of the lymphatics, perhaps up to the nearest glands; the parts thus inflamed are tender and œdematous. If the mischief is limited to the main trunks (*tubular lymphangitis*), they may be felt hard and cord-like, and the red lines remain isolated from each other; but if all the smaller lymphatic channels of a part are affected (*retiform lymphangitis*), the redness merges into a generalized blush, and the condition is identical with cellulitis. Localized foci of suppuration in the course of the lymphatics often follow, the redness increasing and the parts becoming dusky and brawny, until finally the centres

soften and fluctuate. These phenomena are associated with fever and malaise, the temperature rising to 102° or 103°, possibly attended by rigors, vomiting, and diarrhœa.

Under suitable treatment resolution rapidly follows, but suppuration may occur either in the glands or in some loose mass of cellular tissue traversed by the lymphatic trunks, or as a chain of abscesses in the course of the vessels. Occasionally the lymphatic vessels become permanently occluded, and a form of solid or lymphatic œdema results. Recurrent attacks of this type are not uncommon in connection with chronic eczema or ulcers of the leg, and may lead to elephantiasis. In the worst cases the patient dies from general septicæmia, or from exhaustion following diffuse suppuration.

Treatment is at first directed to the causative focus, which must be cleansed and fomented so as to cut off the supply of bacteria and toxins to the lymphatics. The limb itself is kept at rest in a slightly elevated position, and fomented or soaked in a hot bath; Bier's treatment of induced hyperæmia is sometimes useful. Abscesses are opened as soon as they develop. Any subsequent œdema is remedied by massage and firm bandaging, provided no venous complications are present.

Chronic Lymphangitis either results as a sequela of an acute attack, or is met with as a separate condition. It is most frequently seen in connection with venereal disease, the dorsal lymphatics of the penis becoming enlarged, hard, and cord-like, especially in cases of primary syphilis. This is usually accompanied by a solid œdematous condition of the prepuce and enlargement of the inguinal glands. Under appropriate antisyphilitic treatment, the swelling quickly subsides.

A *tuberculous* type of chronic lymphangitis also exists in which a primary focus, say on a finger, is associated with secondary deposits along the lymphatics up the arm. Each nodule is at first of firm consistency, but gradually softens and breaks down. Naturally, such a case is liable to be followed by general dissemination. The *treatment* consists in the excision, if possible, of each focus.

The cheeks and nose are occasionally the seat of a chronic relapsing lymphangitis, due to the absorption of septic material from sores within the nostril. It is characterized by patches of hyperæmia and some amount of tissue infiltration, and for its cure the causative lesions must be treated. The thick lips of a tuberculous child are of a similar nature, and due to the constant irritation of cracks along the lip margin.

Lymphatics, like blood-vessels, are liable to distension and dilatation, which may be either congenital or acquired, and are known as **Lymphangioma** or **Lymphangiectasis.** It is impossible to draw an absolute line of distinction between the two conditions, but the latter term is applied mainly to cases where normal lymphatics are dilated and their continuity with the normal lymphatic circulation persists, whilst a lymphangioma is the result of a new formation. Not unfrequently the two conditions develop side by side.

Lymphangiomas are growths composed of newly-formed lym-

phatics, together with a variable amount of connective tissue, which is sometimes of a fatty nature. They may be congenital or acquired, but even in the latter case there is probably an underlying congenital element, which was only awaiting some irritation or localized injury to determine its development. Two varieties may be described, the capillary and cavernous.

(*a*) The **Capillary Lymphangioma** is usually congenital in origin, but often increases considerably as the child grows, and may attain large proportions. When developing in the skin, it may be termed a **lymphatic nævus,** and in origin and development it well merits the title. The patch is usually of a dull yellowish-brown colour, but this varies with the amount of blood present; it may be smooth-topped like a wheal, or wart-like in appearance, but on examination with a lens each projecting point contains a vesicle. This type of growth is sometimes very extensive, and may be associated with tumours of the underlying connective tissues. Thus, a large fatty mass was removed from the anterior thoracic wall of a child, the greater portion of the projecting surface of which was covered with a capillary lymphangioma. The only *treatment* for this condition is excision or cauterization.

In the subcutaneous tissues the capillary variety is often associated with large cysts of the cavernous type. It constitutes a soft swelling which when cut into has a spongy texture and exudes a large amount of lymph, with some blood. This form is rarely well defined, and may burrow widely, invading and infiltrating the tissues, and, indeed, in some cases may almost be looked on as of a malignant nature. Free excision is the only cure.

(*b*) **Cavernous Lymphangioma.**—The lymphatics here lose their tubular condition and give rise to cyst-like swellings which vary much in size.

In the skin they are rarely larger than a split pea, and may co-exist with the capillary variety. Any part of the body may be affected, and the lesion manifests itself as a series of small vesicles, which persist and are unaccompanied by any inflammatory redness, thus serving to distinguish it from herpes. They contain lymph, and, if opened, a considerable flow of this fluid (lymphorrhœa) may result, lasting for some time. They have been observed most frequently on the inner side of the thigh and on the prepuce. **Treatment** consists in excision, or in laying them open and cauterizing the base.

In the deeper structures large multilocular cystic swellings may be produced; these are most frequently seen in the neck, and the condition is often termed a **Cystic Hygroma** (Fig. 154). Removal by dissection is often very difficult, especially in old-standing neglected cases; the limitations of the mass are sometimes very indefinite, and it may be necessary to leave the wound open and pack it, so as to ensure healing by granulation. Radium may be used.

Lymphangiectases are more frequently acquired than congenital, but the latter condition occurs, and is then probably due to some abnormal development of the lymphatics or to ante-natal inflammatory mischief.

Macroglossia and **Macrocheilia** are congenital enlargements of the tongue and lip, due to lymphatic obstruction and to an associated overgrowth of the connective tissues of the parts.

FIG. 154.—CYSTIC HYGROMA OF NECK.

The condition known as **Chylous Hydrocele,** in which there is an effusion of milky fluid (presumably chyle) into the tunica vaginalis, is probably due to some such obstructive cause. In a case under our care the lymphatics of the spermatic cord were dilated by a similar fluid in a beaded manner.

Elephantiasis is a hypertrophic condition of the subcutaneous tissues and skin resulting from chronic lymphatic obstruction. Two chief varieties are described: (i.) *E. arabum*, due to a development in the lymphatics of living parasites, *viz.* the *Filaria sanguinis hominis* (Fig. 155); (ii.) the *non-filarial* type, which may arise from many causes, such as the deposit of tuberculous or cancerous material in lymphatic glands; the obliteration of lymphatic channels in operations for removing such glands; or from recurrent attacks of lymphangitis in cases of chronic eczema or ulcer, leading to a gradually increasing obliteration of lymphatics. The condition generally affects the legs, but the scrotum is not uncommonly involved, and occasionally the mammæ, arms, or face. The accompanying illustration (Fig. 156, p. 374) indicates that the non-filarial type may be just as severe as the other, although this is unusual.

FIG. 155.—ELEPHANTIASIS ARABUM.

The enormous size of the scrotum is well seen.

Three chief phenomena manifest themselves as the outcome of such obstruction, *viz.* (*a*) *Solid or lymphatic œdema*, a condition in which the subcutaneous tissues become firm, infiltrated, and brawny, but the fluid cannot be expressed from them, as in an ordinary œdema, and hence the part does not pit on pressure. (*b*) *Hyperplasia* follows, affecting not only the subcutaneous tissues, which are greatly thickened, but also the skin, which becomes coarse and wart-like in appearance. (*c*) The warty stage is usually preceded by a development of vesicles (dilated lymphatics) in the papillæ, and from these when ruptured a considerable flow of lymph (*lymphorrhœa*) may follow. If infection

supervenes, chronic ulceration and recurrent lymphangitis may ensue.

Elephantiasis Arabum (see Chapter L).

The **Treatment** is extremely unsatisfactory. In the *filarial* variety, if one can localize the situation of the parent filariæ, as has been possible in a few cases, they should be excised; but even then the lymphatic obstruction may persist. This may be dealt with in either variety by elevation of the limb and elastic pressure; but when the condition is due to lymphatic obstruction in the groin, it may be

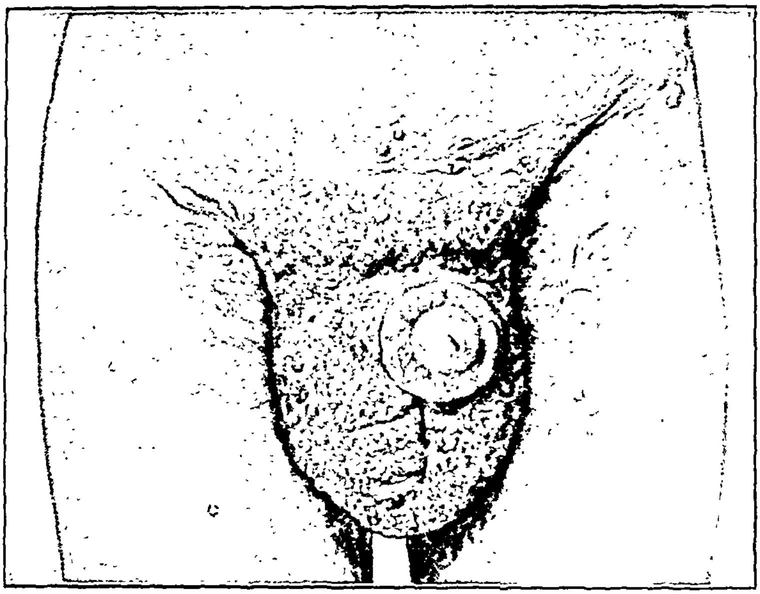


FIG. 156.—NON-FILARIAL ELEPHANTIASIS OF SCROTUM, PENIS, AND THIGHS. (FROM A PHOTOGRAPH.)

The patient was a young man, and the cause of the trouble suppuration of the inguinal glands after scarlatina; the cicatrices of the incisions required in order to deal with the glands are plainly to be seen. The scrotum was much enlarged and very solid; the skin over it was covered with papillomatous growths, due to lymphatic dilatation. The skin of the penis was much thickened, and the subcutaneous tissues infiltrated. Over the thighs were scattered numbers of vesicles, which, when pricked, exuded lymph. and some of these were becoming transformed into solid fibrous growths, The legs and feet were also in a condition of solid œdema.

possible to find the dilated lymph trunks and implant them into a tributary of the internal saphena vein (*lymphangeioplasty*), so as to relieve the limb of its engorgement with lymph. It has also been suggested to construct artificial lymphatics by introducing a carefully sterilized silk thread through the subcutaneous tissues of the thickened area, leaving it buried therein, and carrying it up into normal tissues (Sampson Handley). This has acted fairly well in draining away the fluid from the brawny arms, sometimes seen in the last stages of a cancerous breast (*q.v.*), but it is of little avail in the lower extremity owing to the counter-influence of gravity. Finally, when a limb is

involved, amputation may be desirable. When the scrotum is affected, the morbid tissue can be freely dissected away, sufficient skin being left to cover in the wound if possible; the penis and testes must first be isolated, and then the scrotum amputated, a tourniquet being used to restrain the bleeding.

Affections of Lymphatic Glands.

Acute Lymphadenitis, or Inflammation of Lymphatic Glands.—The **Cause** of this condition is almost always the absorption of some irritative material (toxic or infective) from the periphery. There is always an increased flow of lymph from an inflamed part, resulting in an enlargement of the glands to which the lymph is carried, which quickly subsides when the inflammatory process is at an end. In infective conditions the enlargement is more obvious and painful, and suppuration frequently results; in fact, the lymphatic glands must be looked on as the filters by means of which many sources of disease are eliminated. It is curious that certain peripheral infective conditions are not at all liable to produce lymphadenitis, *e.g.* spreading gangrene and many forms of cellulitis; possibly the acuteness of the process causes lymphatic thrombosis, and thus hinders absorption. A certain amount of periadenitis is always present, even in the early stages; it may be of little importance, or be so severe and extensive as to constitute a diffuse suppurative cellulitis.

Clinical History.—The glandular trouble may be associated with a typical lymphangitis, or be independent of it, and the causative lesion may have almost disappeared before the glands become affected. The glands become enlarged and tender, and if superficial, the skin over them is red and œdematous, and the surrounding tissues are infiltrated and brawny. When pus forms, softening occurs in the centre of the mass, and fluctuation may become evident; where there is much loose areolar tissue around the glands, as in the axilla, the pus may burrow widely. Fever, malaise, and all the general phenomena associated with an acute inflammation, are usually well marked.

Treatment.—The offending wound or causative lesion must be dealt with by such measures as may be needed to hasten its restoration to a healthy state. Fomentations or poultices are applied over the gland, and the patient, after the administration of a purge, may be given quinine and iron, if necessary. As soon as pus has formed, it should be let out by an incision, and the wound dressed antiseptically.

The **Axillary Glands** are usually affected as a result of poisoned wounds of the hand or fingers, although other glands exist lower down in the arm, *viz.* the supracondyloid, just above the internal condyle. Boils in the axilla and excoriations or infected wounds of the breast may also cause an axillary abscess. In this region a suppurative periadenitis is often superadded, extending widely under and between the pectoral muscles, reaching even up to the clavicle. Care must be taken in opening such an abscess to avoid the main vessels by cutting from above downwards, midway between the anterior and

posterior axillary folds, whilst Hilton's method should be adopted in all cases where the pus is situated deeply.

In the **Groin** there are three groups of glands: (1) The oblique set, running parallel to Poupart's ligament, and becoming inflamed in affections of the penis, scrotum, perineum, anus, buttock, and lower part of the abdomen; (2) a superficial vertical set, running with the long saphena vein, and receiving lymph from all the superficial parts of the limb, except perhaps those from which the blood is returned by the external saphena vein, the popliteal glands receiving the lymph from this region; and (3) the deep vertical set, receiving the deep lymphatics of the limb. Abscess in the groin is opened by a vertical incision, so as to allow the wound to gape when the patient sits, and prevent pocketing of matter.

Suppuration in the glands of the **Neck** is exceedingly common, arising most often from affections of the scalp (eczema or pediculosis), ear (otorrhœa or eczema), throat, or lips. As to the exact distribution of the lymphatics, we must refer students to anatomical textbooks. When opening a cervical abscess, care must be taken to avoid important structures, such as the external jugular vein, and to make incisions across the fibres of the platysma in order to gain space for efficient drainage.

Chronic Lymphadenitis.—Three chief varieties of chronic inflammation of lymphatic glands are met with, *viz.* the simple, syphilitic, and tuberculous.

1. **Chronic Simple Lymphadenitis** is a condition resulting from some peripheral irritation, which is insufficient to cause an acute attack. Occasionally it is due to blows or to strains, as in over-walking, being then the outcome of obstruction to the lymphatic flow from compression or rupture of the efferent vessels. The glands become enlarged, tender, and painful, but as a rule they are not adherent to one another or to adjacent structures, and show but little tendency to suppurate. This condition often precedes, and, indeed, may be looked on as a predisposing cause of, tuberculous lymphadenitis. The **Treatment** consists in keeping the part at rest, and removing, if possible, all sources of local irritation. The general health should also be attended to, especially in children predisposed to the development of tuberculous disease.

2. **Chronic Syphilitic Lymphadenitis.**—The lymphatic glands are involved in several ways in the course of syphilitic disease: (*a*) The primary lesion is associated with the development of an indolent bubo in the nearest lymphatic glands (p. 151). (*b*) In the second stage, when general infection has occurred, the glands in many parts of the body are infected in the same indolent fashion (p. 153). (*c*) In the tertiary period the lymphatic glands may undergo a true gummatous change, or become enlarged and tender owing to the absorption of infective material from a broken-down gumma.

3. **Chronic Tuberculous Lymphadenitis** occurs most commonly in children or young adults, and especially in those whose surroundings are unhealthy, and whose general condition is deteriorated by insufficient or bad food and want of fresh air. Some local focus of

irritation is usually present in the form of pediculosis capitis, decayed teeth, chronic otorrhœa, adenoids, or eczema of the face. The bacilli are conveyed to the gland by the blood or lymph, gaining access through some breach of surface, or even through a healthy mucous membrane; or perhaps they may be derived from some deep focus of quiescent tubercle, say in the bronchial or mediastinal glands. Any lymphoid tissue in the body may become the seat of tuberculous disease; but the glands of the neck, which derive their lymph from the mouth, throat, nose, ears, and scalp, are more commonly involved than any others (Fig. 157). The axillary and inguinal glands are not unfrequently affected, whilst tuberculous disease of those in the mesentery gives rise to the affection known as 'tabes mesenterica.' For the general facts as to the pathology of tuberculosis, see p. 171.

FIG. 157.—PHOTOGRAPHS OF A BOY AGED SIX YEARS WITH TUBERCULOUS GLANDS.

Those in the anterior triangle on the right side can be easily seen.

The earliest manifestation of the disease consists in a *fleshy enlargement* of the glands, which cannot at first be distinguished from a simple chronic hyperplasia. The gland may be enlarged to many times its natural size, and on section looks pinkish in colour, and is of firm consistence. Microscopically, all that is noticed is a great increase in the lymphoid corpuscles, together with some overgrowth and thickening of the fibrous capsule and trabeculæ. When tuberculous infection has occurred, the characteristic nodules can be seen under the microscope, but there is at first no change in the naked-eye appearances. *Caseation* follows sooner or later, appearing as foci scattered through the gland, which gradually coalesce to constitute larger masses, which may in time involve the whole (Fig. 158). Should the case recover without suppuration, the gland gradually shrinks, and becomes small, hard, and often closely adherent to surrounding tissues, whilst the caseous material is absorbed, or undergoes *calcifica-*

tion. This latter change is often seen in the mediastinal and mesenteric glands, but is not very common in the neck.

More frequently *suppuration* ensues, sometimes from a simple liquefaction of the caseating material, sometimes from a superadded infection with pyogenic organisms. Foci of pus develop at various spots in the parenchyma, and when once formed, these gradually amalgamate and cause the destruction of the rest of the gland. Several of these abscesses may unite one with another, and thus a large multi-loculated cavity containing pus mixed with caseous débris is formed. A certain amount of *periadenitis* is almost always present, though not to any great extent in the early stages; when, however, suppuration has occurred, the enlarged glands become adherent to one another and to surrounding structures. In the more chronic cases the fibro-cicatricial tissue thus formed may be so extensive as to fix the mass

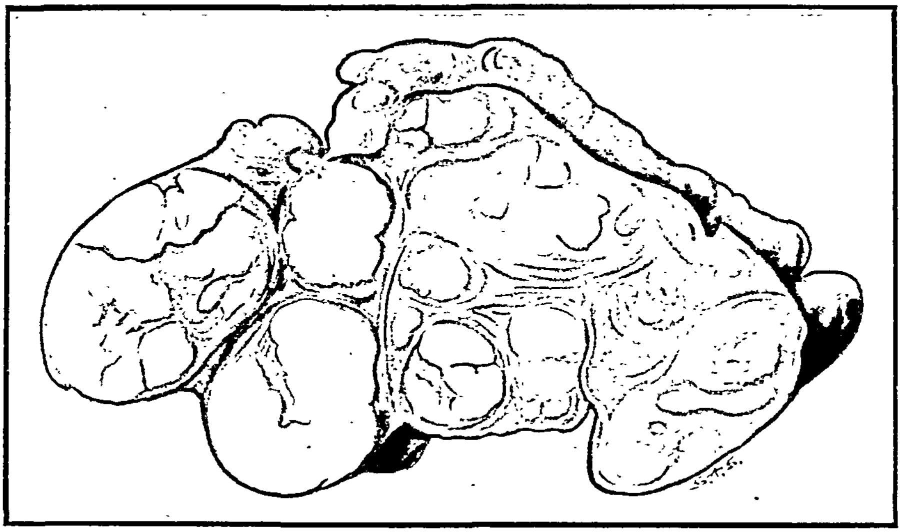


FIG. 158.—CHRONIC TUBERCULOUS GLANDS WITH MULTIPLE FOCI OF CASEATION. (KING'S COLLEGE HOSPITAL MUSEUM.)

firmly to the deeper parts, such as the main vessels and nerves, rendering removal dangerous and almost impracticable. Important vessels are occasionally eroded by an extension of the suppurative process, and this may lead to fatal hæmorrhage. Sooner or later the abscess, if left to itself, bursts at one or several spots, giving exit to the pus and caseous débris, and leaving ulcerated openings, which are surrounded by skin that is undermined, thin, and purplish, and through which granulations protrude. A variable amount of pus escapes from these until all the caseous material has disappeared, so that the condition may persist for many years before healing occurs, and even then the *cicatrix* is often puckered and more or less keloidal, and may retain its vascularity for a much longer period than would a healthy scar. Lymphatic œdema in the region drained by the affected glands is sometimes observed as a late consequence of this affection.

Treatment in the early stages consists mainly in improving the

general health by means of suitable diet and tonics, such as cod-liver oil and syrup of the iodide of iron, together with residence in a healthy, bracing place, especially at the seaside or on high moorland. All sources of local irritation, septic roots of teeth, enlarged tonsils, adenoids, etc., must be removed so as, if possible, to prevent infection with pyogenic organisms; and counter-irritants, such as iodine paint, are best avoided. Rest of the affected part should be enforced as much as possible; in some cases the application of splints to restrict movement is advisable.

Operative Treatment at the present day consists in little more than the aspiration of abscesses when they develop, granting that the overlying skin is healthy. Should the case have been neglected and the skin become red and thinned, the abscess must be opened, and all tuberculous material scraped away, the cavity being subsequently 'bipped,' packed with gauze, and allowed to granulate. It must be remembered that in the neck there is frequently a deep subfascial origin to abscesses, the superficial collection of pus communicating by a small opening in the fascia with a deeper focus of caseous material (collar-stud abscess); unless this latter is dealt with and the caseous detritus scraped away, the wound is unlikely to heal.

If effective treatment of the sanatorium type (p. 175), including exposure to sunlight, the ultra-violet rays of an arc lamp, or to radium, is instituted sufficiently early, extirpation by operative measures will be seldom required, and even then should be limited to isolated groups of glands, such as occur in the anterior or posterior triangles, or the submental region of the neck, or in the axilla. Under no circumstances should the mutilating operations formerly described as desirable in order to remove all enlarged glands in the neck be countenanced. Extensive involvement of the glandular area of this type must be dealt with by intensive sanatorium treatment, as it usually connotes more generalized disease than is immediately apparent.

The *pre-auricular gland* lying on the capsule of the parotid is sometimes affected, and may cause facial paralysis, either as a result of the sclerosing periadenitis, or from injudicious surgery. Any incisions made with a view to remove the gland or to open an abscess therein should be made in the direction of the fibres of the facial nerve, *i.e.* horizontally.

In the *groin*, tuberculous glands are often mistaken for some condition due to venereal disease. The history of onset and the extreme chronicity should suffice to establish a diagnosis. The iliac glands will often be found similarly affected, and well-marked periadenitis is usually present.

Lymphogranuloma inguinale (see Chapter L).

Tumours of Lymphatic Glands.

Lymphadenoma, or **Hodgkin's disease,** is characterized by a progressive enlargement of the lymphatic glands and of the lymphoid tissue of the spleen, liver, and other organs. The affected glands and the masses in the viscera are quite characteristic in structure, and have a very different appearance from that seen in simple hyperplasia

or in infective processes. The gland is homogeneous on section, the distinction between cortex and medulla being lost. The amount of stroma varies considerably, and the glands are hard or soft according to its relative abundance or not. One type does not appear to pass into the other, and the soft form is, in most cases, more malignant and more rapid in growth than the hard. There is a relative decrease of lymphocytes in the glands, and an increase in the endothelial elements, some of which are multinucleated. Nothing is known as to its cause, but it is probably an infective disease.

Hodgkin's disease is generally seen in young adults, but no age is exempt; it is decidedly more common in males than in females. In some cases the cause of the original enlargement of glands is some inflammatory lesion, such as otitis media or dental caries, but often no such origin can be traced. The glands first affected are usually the cervical, and the disease may remain limited to a larger or smaller group of these for a considerable time before other manifestations show themselves (Fig. 159). In other cases internal glands become affected first, and this most commonly in the mediastinal group, the retroperitoneal glands coming next in order of frequency. When the disease is more advanced, lymphadenoid tissue in any part of the body may be affected. The spleen is usually somewhat enlarged, and in about half the cases presents localized greyish-white tumours (the *hard-bake spleen*). Similar growths may occur in the liver, kidneys, etc., or in the skin.

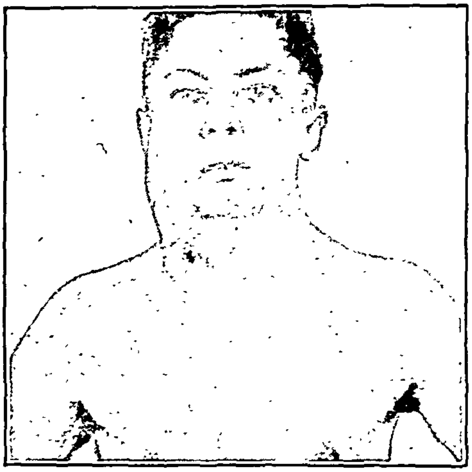


FIG. 159.—PHOTOGRAPH OF A BOY AGED SEVENTEEN YEARS.

The enlargement of the cervical and axillary glands can be seen.

The early symptoms are slight, the only thing noticed being the glandular enlargement. In this stage the glands are soft and elastic, and not adherent to the skin or to one another. When the internal glands are first affected, the earliest symptoms may be those of pressure. This is most marked in the mediastinal group of cases, in which pressure on the superior vena cava is early noted, leading to engorgement of the superficial thoracic veins.

In the later stages intermittent febrile attacks appear, associated with swelling and pain in the glands, possibly due to a superadded pyogenic or tuberculous infection; periadenitis results, and the glands often fuse together, forming hard masses of large size, whilst the disease becomes generalized. The blood shows a moderate grade of anæmia of the secondary type, with a slight increase of leucocytes, especially of the lymphoctyes. Gradually the pyrexia becomes more constant, and the patient passes into a cachectic condition.

Diagnosis.—(1) From *lymphatic leucocythæmia* Hodgkin's disease is recognized by the entire absence of blood-changes in the early stages, and by the presence merely of a secondary anæmia in the later. Moreover, lymphadenoma usually limits itself to regions in which adenoid tissue is normally present; leucocythæmia may develop new growths in any part of the body. (2) From *lympho-sarcoma* it is known by the fact that it is almost invariably limited to the glands, and does not infiltrate surrounding tissues. Lympho-sarcoma is characterized chiefly by its tendency to infiltrate, and also by producing secondary deposits in tissues which are not rich in adenoid tissue. (3) From *tuberculous disease* of glands the diagnosis is often difficult. Tubercle is more common in the very young, and is more frequently bilateral. The glands have a greater tendency to fuse together as a result of peri-adenitis and to suppurate. In doubtful cases microscopic examination of an excised gland may be required to settle the diagnosis.

The **Treatment** of Hodgkin's disease consists in the administration of arsenic and the exposure of the enlarged glands to X-rays or radium. Arsenic must be administered in the form of intravenous salvarsan; oral administration is of little use. X-rays seem to have a marked and rapidly beneficial effect over this condition. Operative treatment is useless; in the early stages it is easy, but unsuccessful, as recurrence almost invariably follows; in the later stages, when several attacks of inflammation have occurred, it may be most difficult, and indeed practically impossible, to remove the glandular masses. Unfortunately the good effects of arsenic and irradiation cease after a time, and nothing suffices to hinder the downhill progress of the patient.

Lymphatic Leucocythæmia is of little surgical interest except in so far as it simulates Hodgkin's disease. The symptoms are much more severe than in the latter, and marked blood-changes are present; the number of the leucocytes is enormously increased, reaching 150,000 or more per cubic millimetre, and there is a great preponderance of lymphocytes, which constitute from 90 to 99 per cent. of all white cells present. There is also anæmia, often of some severity. It is often associated with changes in the spleen and medulla of the long bones, characteristic of the spleno-medullary type of leucocythæmia. In its treatment arsenic is of some value, and X-ray treatment directed to the spleen and ends of the long bones, as well as to the glands, has been used with temporary benefit. It is also stated that if the patient's general condition can be improved sufficiently by blood transfusion, removal of the spleen is beneficial and curative; but the danger of the operation is considerable, and sufficient time has not yet elapsed to dogmatize as to results.

Lympho-sarcoma.—This term has been used with very different meanings, but is best restricted to tumours which have a structure approximating to that of lymphadenoid tissue, *i.e.* which consist of small round cells, resembling, if not identical with, ordinary lymphocytes, set in a reticulated stroma; there is no distinction between cortex and medulla. They closely resemble a small round-celled sarcoma, except that the stroma is more obvious; their sarcomatous

nature is evidenced rather by clinical than by histological characters, *viz.* by the fact that they invade and destroy surrounding tissues.

Lympho-sarcoma may commence in any part of the body, but in the vast majority of cases it originates in pre-existing adenoid tissue, most commonly in the glands at the root of the neck (Fig. 160), the tonsil, or the mediastinum. It may also affect the intestines (commencing probably in the Peyer's patches) or the testis. When developing in a region where its progress can be followed, it is seen to form a rapidly-growing tumour, which is at first firm, elastic, and painless; later on, however, as it increases in size, it becomes tender, and may cause great pain from pressure on, or implication of, nerves. It early contracts adhesions to surrounding parts, and gives rise to secondary growths in neighbouring glands by direct transmission. The superjacent skin is at first unaltered in colour and texture, but

FIG. 160.—EXTENSIVE LYMPHO-SARCOMA OF THE NECK.

FIG. 161.—LATE STAGE OF LYMPHO-SARCOMA, SHOWING ULCERATION.

as the tumour increases it becomes congested and shiny, and contains a network of dilated veins. Finally, ulceration occurs (Fig. 161), and is followed by the sprouting up of a bleeding fungating mass, similar in character to that formed by any other rapidly-growing malignant tumour. Dissemination of the growth throughout the viscera follows, death resulting from exhaustion and cachexia.

The **Treatment** consists in inserting radium needles into the growth, because this type of tumour is extremely sensitive to radium therapy. Quite large masses can be made to disappear in a short period of time. However, local recurrences do occur, and are more radio-resistant.

Secondary Growths in Lymphatic Glands are a special feature of all cancerous tumours and melanomata. In the sarcomata they are less common, but are always present in the case of lympho-sarcoma, and usually in sarcoma of the testis, tonsil, and thyroid. The special characteristics of these are noted elsewhere.

CHAPTER XV.

AFFECTIONS OF NERVES.

Contusions and **Strains** cause a sensation of tingling, or of pins and needles, which usually wears off in the course of a few hours. In severe cases variable degrees of loss of power and sensation may ensue, associated with more or less neuralgia, and in patients suffering from gout, syphilis, or rheumatism chronic peripheral neuritis develops, often of a somewhat intractable type. **Treatment** consists in friction, with stimulating liniments in the slighter cases.

Concussion of a nerve is characterized by the more or less complete loss of its function without any apparent lesion. It has been frequently observed as the immediate result of the passage of a bullet or fragment of shell close to a nerve. There is no shooting pain associated with the injury, and the anæsthesia does not correspond with any definite peripheral nerve distribution, but is limited to the area over which the loss of power is confined. The muscles rarely waste, and faradic excitability persists. Apart from infection, repair shows itself within two or three weeks, and is usually completed within three or four months. If, however, the wound becomes infected, the condition may be followed by compression due to cicatricial contraction. It is probable that the loss of conductivity is due to molecular disintegration of the axis cylinders or to minute hæmorrhages.

Massage and electricity are desirable elements in the treatment, but in the later stages much can be done by suggestion and persuasion.

Compression of a nerve may arise from many different causes, and the clinical picture varies somewhat according to the history and the particular nerve involved. (1) It may be due to *direct traumatism*, *e.g.* the pressure of a crutch in the axilla, the musculo-spiral nerve being generally affected; the presence of a cervical rib may cause pressure on the lower brachial nerves (p. 411); undue prominence of the ulnar nerve behind the elbow, perhaps due to cubitus valgus, exposes it frequently to injury; or a superficial nerve may be compressed between the splint and an underlying bone, as where the external popliteal nerve passes over the neck of the fibula. (2) It may be caused by the *contraction* of cicatricial tissues in an infected wound, or by the development of *callus* in a fracture, *e.g.* the musculo-spiral in fractures of the shaft of the humerus, whether open or closed. Some immediate loss of function may result either from concussion or partial laceration, or from a combination of these factors. Improvement of the symptoms may for a short time accompany healing of the wound, but subsequently the nerve is constricted by contraction of the scar tissue. (3) *Tumours and aneurisms* frequently produce nerve compression.

In the majority of cases the symptoms are more or less similar. Irritative phenomena appear early, and are manifested by cramp or spasm of muscles, associated with neuralgic pain; later, there is loss of function of the muscles supplied by the damaged nerve, together with anæsthesia, corresponding to its peripheral distribution. As a rule, the paralysis is incomplete, the nerve not being divided, and wasting is not generaly a prominent feature. The loss of protopathic sensation (pain on pin-prick) is greater than that of the epicritic sense (touch with camel-hair brush), which is contrary to that usually seen in division of a nerve (Stopford). Some degree of recovery may be looked for after removing the cause of the compression, and the progress will depend upon the amount of permanent structural change which the nerve has sustained. In many cases operative measures (*neurolysis*) are indicated, and care must be taken to prevent the recurrence of the development of scar tissue. Implanting the nerve within a healthy muscle belly or wrapping it round with an autogenous pad of fat is probably the most satisfactory method of securing this end. In some cases the cause can be effectively dealt with, as by removal of a cervical rib, or by transplanting the ulnar nerve from the back to the front of the internal condyle.

The nerve is sometimes merely *adherent* to a scar, in which case the main symptom is pain brought about by movements which drag on the nerve. The prognosis of these cases is fairly good, providing the nerve can be freed and protected from further pressure by a fatty pad. Ionization of the scar or its treatment by radium emanations may be tried as a preliminary measure.

Rupture of nerves without an external wound only occurs in connection with severe injuries such as dislocations or fractures, and even then total division is rare, the sheath retaining its integrity, although the axis cylinders may have given way. Immediate paralysis and loss of sensation usually follow, and may persist for a time, although repair not unfrequently occurs, since the sheath remains intact. The doubt always existing as to the condition of the sheath regulates the **Treatment** which must be followed, *viz.* one of expectancy. Massage and electricity should be applied to the affected muscles, which are placed in a position permitting their complete relaxation so as to prevent them from stretching; only when a sufficient trial has been given to these should operation be undertaken. Secondary nerve suture under these circumstances is not a very successful proceeding.

Total Division of a Nerve may result from any type of penetrating wound, *e.g.* stabs, or from the missiles used in war. In civilian practice wounds produced by ragged fragments of glass are often associated with nerve injuries. At the moment of infliction of the wound the patient usually experiences a sharp shooting neuralgic pain, which he describes as similar to an electric shock, shooting up or down the limb.

The **Immediate** effects are: (*a*) Paralysis of the muscles supplied by the nerve; (*b*) complete anæsthesia of the parts supplied by it, which, however, is not necessarily permanent, since sensation may be conveyed by collateral trunks, the anæsthetic area passing through

gradual stages of partial sensation before recovery is complete. (*c*) Vasomotor paralysis is also produced, the limb becoming hyperæmic and warmer for a few days, and then subsequently colder and insufficiently supplied with blood. (*d*) The excito-secretory nerves are paralyzed, so that glands lose their functions for a time.

The **Secondary** effects vary with the character of the nerve injured, whether motor, sensory, or mixed; with the condition of the wound, whether infected or not; and with the possibility or not of early coaptation of the divided ends.

1. **Changes in the Nerve.**—*Locally*, the two ends retract, and the space thus formed fills with blood, which is quickly absorbed and replaced by granulation tissue, and this in turn by a bulb-like mass of fibro-cicatricial tissue (*terminal neuroma*), within which are found spaces filled with fine nervous fibrillæ coiled up in loops. After an amputation, most of the divided nerves are found to have developed these typical bulbous ends (Fig. 162), whilst in nerves accidentally severed in their continuity the bulbous mass which forms on the upper end is separated by an interval from the atrophied lower end, though there is often a fibrous connection between the two (Fig. 164, *A*). These bulbs may be the seat of severe neuralgia. In a few rare instances immediate union of a divided nerve is supposed to have occurred, as indicated by total and rapid restoration of function.

FIG. 162.—TRAUMATIC NEUROMA OF POSTERIOR TIBIAL NERVE AFTER AMPUTATION OF LEG. (FROM KING'S COLLEGE HOSPITAL MUSEUM.)

Peripherally, the so-called Wallerian degeneration commences about the fourth day after the accident, in consequence of the separation of the nerve from its trophic centres. The medullary substance undergoes a form of segmentation, and is broken up into irregular masses of myelin, which are absorbed by leucocytes or connective-tissue cells, and disappear entirely in about a month. The axis cylinders also degenerate and disappear. The neurilemma cells proliferate in columns and form a fibro-cellular rod, in which all power of conducting nervous or electric stimuli is lost.

2. **Changes in the Muscles.**—Complete paralysis of motion necessarily occurs when a motor nerve has been divided, and the muscles involved waste and undergo degeneration. The atrophy is not so rapid as that arising from infantile palsy, since it is simply due to separation from the trophic centres, and not to their destruction. Unless the paralyzed muscles are kept in a position of relaxation, they become stretched and elongated, and then, even if satisfactory repair of the nerve is secured, restoration of function is almost im-

possible. For example, in musculo-spiral paralysis all the extensor muscles of the wrist and hand become hopelessly elongated unless the wrist is maintained in a position of hyper-extension on a 'cock-up' splint.

The *electrical* changes, too, are important. The faradic current rapidly loses its power over the paralyzed muscles, and its effects totally disappear in two or three weeks, whilst the galvanic excitability remains for weeks or months, and even then only slowly diminishes, so that a condition develops in which the galvanic current produces a much greater contraction than the faradic (*reaction of degeneration*, p. 300). As long as this phenomenon remains, there is a hope that restoration of the continuity of the nerve may be followed by restoration of function; but when the muscles react neither to galvanic nor to faradic stimuli the case may be looked upon as beyond repair.

3. Various modifications of **Sensation** are produced. Head and Sherren have demonstrated that different types of sensory impulse are carried by separate groups of nerve-fibres, and that the peripheral distribution of these varies considerably. (*a*) *Deep* sensation consists in the appreciation of pressure, including heavy touch and painful pressure, and in the recognition of the positions and movements of joints and muscles. These stimuli are carried by motor nerves, and distributed to muscles, tendons, ligaments, etc. Section of all the sensory nerves to the skin of a part does not destroy this form of sensation. (*b*) *Protopathic* sensation takes cognizance of painful cutaneous stimuli, and of the effects of temperatures below 20° and above 50° C. The distribution is somewhat indefinite and diffuse, following rather the nerve-root areas than those of the peripheral nerves. The superficial extent supplied by a particular nerve is only recognized when all other sensory nerves to the part are divided, and is liable to vary considerably. The overlapping of these areas will explain the persistence of certain forms of sensation when the nerve apparently supplying that area has been divided. (*c*) *Epicritic* sensation includes the appreciation of light touch (as by a wisp of wool), the localization of stimuli, the recognition of moderate degrees of temperature (between 20° and 40° C.), and the power of discriminating between two stimuli simultaneously applied, as by the points of a compass; its distribution corresponds with fair accuracy to that of the peripheral nerves.

Section of a purely sensory nerve causes loss of the epicritic and protopathic forms of sensation only, but the area over which the epicritic sense is lost (Fig. 163) is greater than that over which protopathic sensation is absent owing to the overlapping of neighbouring nerve areas. Section of a mixed nerve causes loss of all three types of sensation in any area exclusively supplied by that nerve, but if there is much anastomosis with neighbouring nerves protopathic sensation is little affected. Section of a posterior nerve-root affects protopathic sensation more extensively than the epicritic. In incomplete division or injury of sensory nerves, epicritic sensation is abolished more extensively than protopathic.

4. The blood-supply to a paralyzed part is diminished, and the

circulation feeble; hence the extremities usually become cold and their vitality lowered. Chilblains are readily produced, and the unwise application of heat may cause blistering or even sloughing. Wounds heal badly, and ulceration from slight irritants is very likely to occur, *e.g.* corneal ulceration after division of the fifth nerve, and perforating ulcers of the foot after division of the sciatic nerve. Atrophy of the smaller bones may follow, and ankylosis of the terminal joints of the fingers or toes. In a growing child the development of the part is always more or less impaired. As a general rule, the sweat secretion ceases, and the skin over the anæsthetic area becomes dry and scaly, so that one can often see its extent and limits. All these phenomena are more marked when some irritative pressure exists, as by a foreign body or the presence of scar tissue.

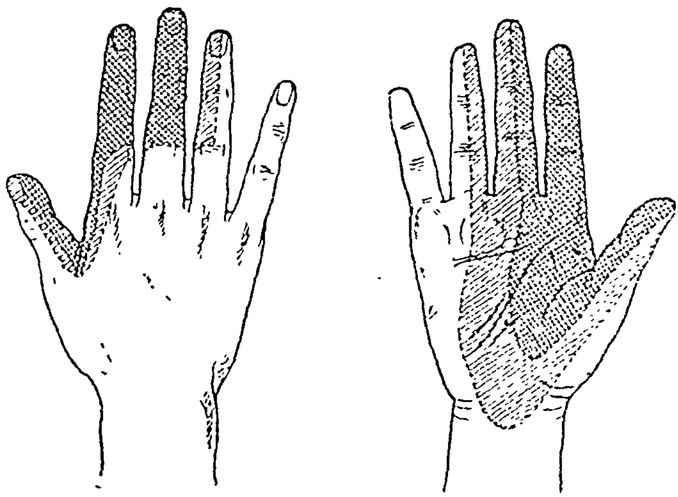


FIG. 163.—USUAL TOPOGRAPHY OF SENSORY DISTURBANCE AFTER SECTION OF THE MEDIAN NERVE.

The area of lighter shading is one of hypo-æsthesia; that more darkly shaded is completely anæsthetic.

5. In a few cases changes have developed in the central nervous system which are of much interest. In the early stages reflex spasms or paralyses are sometimes met with as temporary phenomena; at a later date more serious symptoms may result, such as epilepsy, but the explanation is not easy.

Incomplete division of nerves is by no means uncommon, especially in wounds produced by the penetration of fine cutting instruments, or of small conical bullets or of fragments of high-explosive shells.

Should the nerve be notched, the divided fibres retract and leave a gap, which, after a time, is filled by a fibrous mass permeated with embryonic axis cylinders, constituting a **lateral neuroma** (Fig. 164, *B*), over which are spread the undivided fibres of the nerve. This neuroma may be adherent to the scar tissue which reaches the skin, and may be the site of severe neuralgic pain.

A large nerve-trunk is sometimes penetrated by a small fragment of metal or missile, and some of its central fibres divided: in such

cases a **central neuroma** (Fig. 164, *C*) may develop, around which pass the healthy nerve-fibres, and the bulbous enlargement so produced can often be felt from outside, and may be freely movable.

The phenomena resulting from partial division of a nerve vary considerably. Certain groups of muscles are more liable to be affected than others supplied by the same nerve, and this is to be explained by the fact that there is a definite arrangement of the various bundles of fibrils in the nerve, and some portions of the nerves are more exposed to injury than others. Thus the fibres running in the great sciatic nerve to the external popliteal division are external to those constituting the internal popliteal division, and are thereby more liable to be injured. Details of the intratruncular arrangement of the fibres in different nerves must be sought in special works.

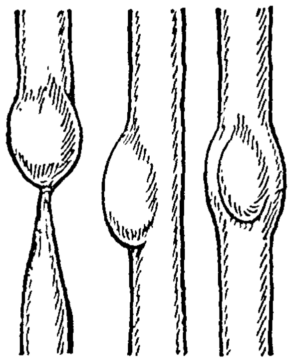


FIG. 164.—DIAGRAMS OF FORMATION OF NEUROMA ON INJURED NERVES.

A, Total division with terminal neuroma; *B*, partial division with lateral neuroma; *C*, perforation with central neuroma.

Partially divided nerves are sometimes the site of persistent and serious irritation, especially if a fragment of glass or metal remains embedded at the site of the lesion. Trophic phenomena, often of a grave character, may then supervene in the distal parts supplied by the nerve. The skin becomes thin, atrophic, bluish-red, and shiny ('glossy skin' of Weir Mitchell); the subcutaneous fat is absorbed; the hairs fall out; the nails become rough, brittle, and scaly; and the sebaceous sweat glands discharge an abundant secretion. The bones atrophy, joints become ankylosed, and ulcerative lesions occur on the slightest provocation.

In other instances, pain is the most marked feature, especially in partial lesions of the median and sciatic nerves. The pain is of a burning character (*causalgia*), felt in the palm of the hand or sole of the foot, and brought on by touching the part, or by emotional stimuli, such as sudden noises. It is usually increased by even moderate degrees of heat or cold, and by any movements which drag on the nerve; it prevents sleep, and is very intractable. Its origin is somewhat doubtful, but it is possibly due to a spreading fibrosis of the nerve-trunk leading to compression of the nervi nervorum.

Wound infection adds a grave element to the damage caused by injuries to nerves. During the acute stage the exposed nerve-ends suffer equally with other tissues in the early destructive and later reparative processes necessary to combat infection. The development of scar tissue, moreover, introduces a barrier between the divided ends of the nerve. Bacteria and their toxins also gain access to the interior of the nerve, and travel up the interfibrillar spaces, perhaps for inches; reactive formation of connective tissue ensues, leading to fibrosis, which may extend for some distance and seriously hamper repair.

The mere exposure of an undivided nerve in a suppurating wound is similarly liable to be followed by fibrosis.

Regeneration of a divided nerve must necessarily precede restoration of function. Attempts at regeneration are always evident in the distal segment, whether or not it has been sutured to the upper end, but in the latter case the phenomena are never carried to perfection, owing to the intervention of the end-bulb. When this has been removed and effective end-to-end suture established, the axis cylinders of the proximal segment grow downwards and force their way along the sheath of the nerve, in which active preparations have been taking place, and from which the restoration of the varied elements of the sheath is determined. In any case, the process is slow and takes many months to reach completion. It is possible that under favourable circumstances an interval of half an inch or even more may be bridged by this process, but it is unusual. A nerve-graft may serve to direct the energies of the neuroblastic cells, but is probably quite passive. Clinically, the earliest evidence of regeneration is a slight return of sensation, which is at first protopathic, and only slowly becomes of an epicritic type. Motion is generally much later in its restoration than sensation, and may never be entirely recovered.

Treatment.—It is of the utmost importance that every divided nerve of sufficient size, especially if containing motor fibres, should be at once dealt with, if possible, by **Primary Nerve Suture.** This is best accomplished by using a domestic sewing needle without cutting edges, or a fine Hagedorn needle, and the finest catgut or silk; the nerve-ends should be brought into apposition without tension or torsion, and secured by sutures passing merely through the sheath. Steadying stitches through the nerve are undesirable if they can be avoided. Absolute asepsis is essential in order to obtain satisfactory results. It is most desirable that the nerve should be protected from the pressure of adhesions by burying it in a bed of healthy muscle, or by wrapping around it a thin pad of fat or fascia. In wounds involving the nerves about the wrist the deep fascia should also be carefully sutured to prevent the formation of adhesions between the nerves and tendons to the skin, whereby subsequent mobility would be impaired.

It is often impossible to undertake nerve suture as a primary procedure, and operation for **Secondary Nerve Suture** at a later date is frequently found to be necessary. (1) It is as a rule useless to attempt suture in an infected wound, and inasmuch as organisms remain in a latent state in the scar tissue of such a lesion operation must be delayed for some months after healing has occurred. (2) In not a few cases it is difficult at first to make certain that a nerve has been actually divided, and that the loss of power, etc., is not due to concussion or partial laceration from which spontaneous recovery may be expected. Here again operation may be justifiably delayed.

Pre-operative treatment during the period of waiting is most important. (1) *Postural.*—The limb is placed on a splint or in a contrivance that will relax the paralyzed muscles and prevent them from becoming over-stretched. Thus, in a musculo-spiral lesion the hand must be kept in a position of hyper-extension at the wrist-joint, in

order to prevent wrist-drop. If the sciatic or external popliteal nerve is paralyzed, 'foot-drop' occurs, and a gaiter must be worn to prevent this by the use of springs or elastic tractors. (2) During this time the joints of the limb—fingers, toes, wrist, ankle, etc.—must be kept supple by daily *manipulation and movement* so as to prevent stiffness. The application of a splint for a long time without this precaution may result in extensive adhesions in joints and tendon sheaths, which will increase the trouble already present. (3) The tone of the paralyzed muscles must be maintained by *massage* and regular *electric treatment*. The galvanic current should be employed in the form of an electric bath, or the sinusoidal current may be used. The limb must also be kept warm by suitable coverings, as its circulation and nutrition are defective, and the limb must always be well warmed before either massage or electricity is applied.

The **operation,** though easy to describe, is one often performed with difficulty owing to the density of the scar tissue in which the ends of the nerve are buried. It is essential, therefore, to make extensive incisions in order to expose the nerve-trunk both above and below the lesion; the scar tissue is divided cleanly, and if possible removed, until the bulbous end above and the atrophied end below are freed. The bulb and fibrous junction are removed sufficiently to expose healthy nerve-fibres both above and below; it is desirable to test the lower end of the severed nerve by a weak faradic current. The ends are then stitched together as accurately as possible so as to appose similar portions of the nerve sections.

Some practical points may be noted which, if adopted, will enhance the success of the operation. (1) The nerve must be very gently handled; broad gauze strips passed under the nerve are more satisfactory than metal retractors. (2) The nerve must not be allowed to become chilled, but should be wrapped in gauze soaked in warm salt solution. (3) The question of *bridging an extensive gap* between the nerve-ends is one that is often difficult to settle. (*a*) There is a certain amount of extensibility of a nerve-trunk if it is completely freed for a considerable distance up and down. (*b*) Position of the limb is of great assistance, *e.g.* flexion of the wrist, elbow, and knee; but it must be remembered that when dealing with the ulnar nerve above the elbow, flexion of the joint increases the tension; it is wiser under such circumstances to dislodge the nerve from its interval between the internal condyle of the humerus and the olecranon process, and bury it in the muscles in front of the condyle. (*c*) Bridging the gap by the union of flaps cut from the upper and lower ends; the lateral implantation of the divided ends into a healthy nerve; the interposition of a tube, such as a vein or of a nerve-graft, between the two ends in the hope that the axis cylinders may thereby be enabled to travel downwards—all these methods have been tried sufficiently often to demonstrate their inefficiency. (*d*) The removal of a segment of the bone of the limb so as to shorten it permits of the accurate apposition of the nerve segments, but it is a serious addition to the operation, and should never be undertaken lightly. (*e*) Where all such procedures fail or do not commend themselves to the operator, the

untrimmed ends of the nerve should be drawn as closely together as possible by stout tension stitches passed through them, and the limb placed in a relaxed position. After healing has occurred, the limb may be gradually straightened, the nerve being thereby stretched, and at a later date a second operation may succeed in securing coaptation of the trimmed ends.

In cases of incomplete division or compression of a nerve, it is sometimes difficult to decide on the appropriate treatment. A *lateral neuroma* should be dissected away, retaining carefully any nerve-fibres that appear to be healthy; the exposed surfaces are then drawn together by sutures so as to coapt the freshly divided fibres, and the healthy ones are allowed to form a loop at the side (Fig. 165).

A *central neuroma* may similarly be dissected away after dividing the sheath by a free longitudinal incision, which permits the healthy nerve-fibres to be drawn aside unharmed.

The treatment of *causalgia* is one of great difficulty. No drugs appear to have any control over it except morphia; wet and cold

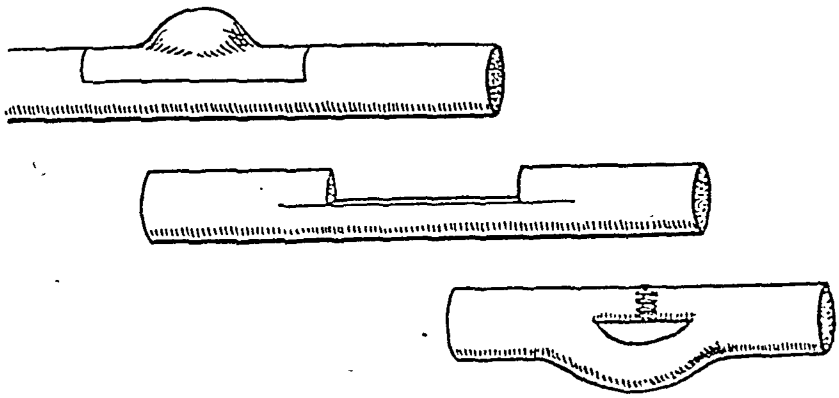


Fig. 165.—Operation for Removal of Lateral Neuroma from Partially Divided Nerve.

applications to the hands or feet seem to be of some value. Injection with 80 per cent. alcohol may destroy the pain, but of course also destroys the function. If operation is undertaken, simple freeing of the nerve from the compression of scar tissue may suffice, but as a rule the sheath should be opened by a longitudinal incision and the interior of the nerve explored. If it is soft, and the function of the nerve is moderately good, this should suffice; if it is hard, and the function of the nerve poor, excision and suture must be undertaken.

It is not fair to compare the *end-results* of these secondary operations with those of primary suture. The nerves are often embedded in scar tissue and are in a condition of fibrosis due to the infection of the original wound; the removal of these fibrous ends, together with the detachment necessary to permit of approximation, is liable to bring into contact two sections of the nerve of slightly different intratruncular pattern, so that quite apart from torsion it may result that motor axons find their way into sensory fibres or *vice versa*; indeed, when one considers the small size of the nerves to the smaller

muscles of the hand or foot, it is wonderful that axis cylinders ever find their way correctly. Finally, the necessary delay always results in some degree of muscular degeneration or fibrosis, and repair becomes increasingly difficult as time passes. The musculo-spiral nerve supplying large muscles with gross movements gives the best results; the sciatic and external popliteal nerves are fairly favourable, although the intrinsic muscles of the foot often fail to recover; the results of operations on the median and ulnar nerves are often disappointing, especially in the lower parts of the forearm, and complete restoration of function of the palmar muscles is uncommon.

Sensation of a general type may be restored quite early, but this often disappears again, and is only regained slowly after some interval; deep sensibility returns first, then protopathic sensation, and finally epicritic. Motor power is developed proximally at first, and gradually spreads downwards; at first all that may occur is a more brisk response to the galvanic current; voluntary movements often precede the appearance of faradic excitability. The trophic appearance of the limb and its general condition often improve considerably before any signs of movement appear. The date of recovery varies much, especially with the interval since the nerve was divided; the longer the interval, the later the restoration of function. It also depends upon the site of the injury, as obviously in lesions high up in the limb there is a larger segment of the nerve to be repaired. A musculo-spiral nerve may be expected to recover fully in six to eight months; a median or ulnar nerve wounded and sutured above the elbow has done well if the movements are restored in six to twelve months; an external popliteal nerve may be restored completely in four to eight months after suture; but a great sciatic nerve, wounded high up in the thigh, takes probably two years to be repaired.

During all this time the precautions and treatment needed in the pre-operative period of the case must be maintained, and one can realize how bored the patients become, and how persistently patient and persevering must be the medical, massage, and electrical attendants. *The patient's will-power must be exercised to assist in driving nerve impulses across the gap and down the distal segment, and re-educational exercises must be employed as soon as some amount of volitional power has been regained.*

A useful sign of progressive regeneration of the nerve after operation is that described by Tinel, although satisfactory repair can occur in its absence. On pressure or light percussion of the trunk a little distal to the site of the suture, a subjective sensation of tingling or stinging is experienced six or eight weeks after the operation, and as time passes it is possible to elicit this sign at a gradually lower level; it is due to the growth downwards of the new axis cylinders. Naturally in the musculo-spiral nerve, where there are few sensory fibres, it is not frequently elicited. It is advisable to employ this test from below upwards.

Finally, when all efforts to make good a divided nerve have failed, various tenoplastic procedures designed to counteract malpositions may be undertaken, or amputation may be required.

Acute Neuritis is not very common. It is sometimes due to injury, gout, or rheumatism, but is usually observed in connection with infected wounds. The nerve is swollen and becomes tender, whilst severe pain of a neuralgic type is often experienced. On microscopic examination the ordinary signs of inflammation are well marked, though mainly in the sheath. The **Treatment,** when not due to infection, consists of rest to the limb, together with leeching or dry-cupping over the course of the nerve, combined with belladonna fomentations and suitable general therapeutic measures.

Chronic Neuritis, or **Perineuritis,** is much more common than the former. It consists pathologically in an increase of all the connective tissue of a nerve, both around it and between the fasciculi, with compression of the vessels and nerve-fibres. It may result from injury, such as sprains, strains, or pressure, especially when the patient is suffering from syphilis, rheumatism, or gout, and is met with after influenza and in various toxic conditions, *e.g.* alcoholism, diabetes, malaria, etc. Apart from injury, neuritis is usually a manifestation of *fibrositis,* and not unfrequently fibrous nodules can be detected on careful palpation, either involving or attached to nerve-sheaths; the extreme tenderness of many of these nodules also suggests the involvement of nerves. Highly sensitive spots are also found on the roots of the nerves, as they emerge from the spine, also where they pierce aponeuroses or deep fasciæ. The **Symptoms** vary a good deal with the nerve affected, which can occasionally be felt thickened and tender on pressure. More or less severe neuralgia results, accompanied by loss of power in the case of a motor or mixed nerve. Trophic lesions may also be induced, such as perforating ulcer, or ankylosis of the terminal joints of fingers or toes. The phenomena are usually much influenced by changes of weather.

Treatment is mainly directed towards removing the source of the trouble. All foci of toxic absorption are suitably dealt with, whether involving teeth, tonsils, nasal sinuses, appendix, gall-bladder, or colon. Where operative measures are not indicated, vaccine treatment may be possible. Digestion must be improved, and the dietary modified to suit the individual requirements. Hydro-therapeutic measures should be instituted, whether at a spa or at home; in the latter case a small dose of saline purgative, *e.g.* Epsom or Glauber salts, or a mixture of the same, should be taken each morning before breakfast in half a pint of warm water, and a tumbler of cold or hot water half an hour before each meal; no fluid is allowed at meals. Pain is combated by aspirin or similar drugs, but in bad cases morphia may be required at night. *Locally,* the affected part must be kept at rest until the pain and tenderness disappear, the arm, for example, being placed in a sling. Warmth of the affected area is an essential, and mild counter-irritation, as by the use of thermogene wool, is desirable. Massage in the early stages is as a rule injudicious, but gentle inunction with an iodine preparation, as, *e.g.*, iodex combined with methyl salicylate, is often helpful. Electric baths are useful, the current passing from the limb, which is placed in a receiver containing a solution of bicarbonate or iodide of sodium, to a pad moistened with

sodium chloride placed over the spine. As the condition improves, massage either alone or combined with hot douches (Vichy or Aix douche) is of great assistance. If there is any paresis, the muscles must be stimulated by the faradic current, and re-education exercises may be required.

Tumours of nerves are very rare except when occurring on some of the cranial nerves (see p. 409).

Very occasionally a tumour may be found on one of the nerves of the limbs (Fig. 166), in which case it is of the nature of a leiomyoma.

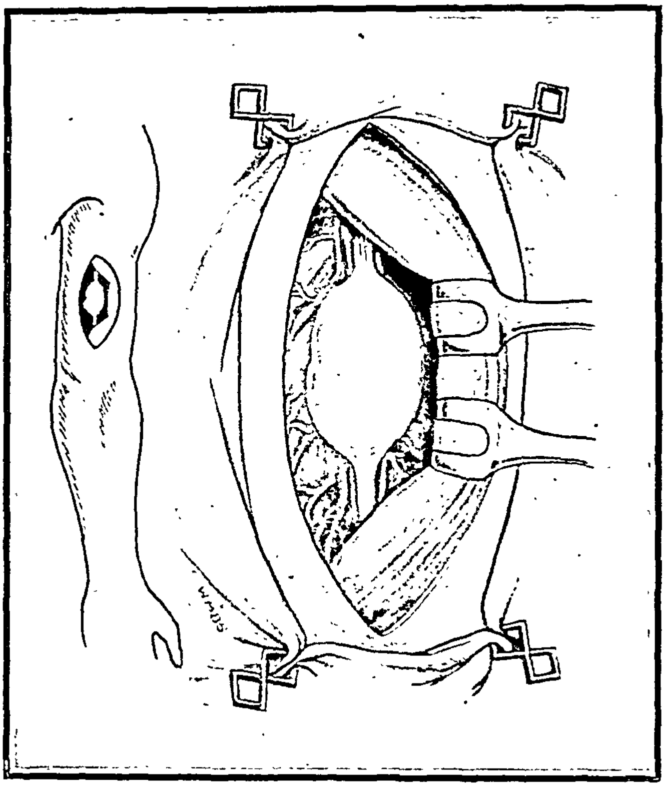


FIG. 166.—LEIOMYOMA OF THE MEDIAN NERVE, SHOWING THE TUMOUR AS SEEN AT OPERATION.

Affections of Special Nerves.

The Cranial Nerves.—The **Olfactory Nerve** may be involved in fractures extending across the cribriform plate of the ethmoid, or in severe cases of contusion of the anterior lobes of the brain without fracture, resulting in loss of smell (anosmia).

The **Optic Nerve** is sometimes ruptured in fractures of the base of the skull running into the optic foramen, or divided by penetrating or bullet wounds, leading to sudden irremediable blindness; or it may be compressed by effused blood or inflammatory exudation, either within or outside of its sheath, causing more or less complete loss of vision; if the hæmorrhage has not been very extensive, vision may

be in measure restored. Orbital cellulitis not unfrequently causes pressure on the nerve, either immediately as a result of the inflammation, or subsequently by cicatricial contraction. Syphilitic disease of the sheath, or the formation of a gumma in its neighbourhood, or intra-orbital aneurisms or tumours, may likewise interfere with vision from pressure on the trunk. Optic neuritis, or more accurately acute papillœdema, is an œdematous condition of the intra-ocular termination of the nerve in the fundus oculi, due to increased tension of cerebro-spinal fluid; it is a frequent result of cerebral tumours or inflammation, and is generally followed by optic nerve atrophy and blindness.

The **Third Nerve** (*motor oculi*) being entirely motor, paralytic symptoms are those to be looked for. They may arise from *central* causes, such as syphilitic or degenerative changes in the floor of the third ventricle; or from *peripheral* lesions, such as aneurisms, tumours, gummata, trauma, etc., either in the orbit, sphenoidal fissure, or base of the skull. The **Symptoms** of complete paralysis are as follows: (*a*) Ptosis, or drooping of the upper eyelid, from loss of power in the levator palpebræ; (*b*) external strabismus, or squint, from paralysis of the inner, upper, and lower recti, the eye being also directed a little downwards from paralysis of the inferior oblique; (*c*) mydriasis, or dilatation of the pupil, from palsy of the iris; (*d*) loss of accommodation, from the ciliary muscle being paralyzed; and (*e*) some slight protrusion of the eyeball (exophthalmos), owing to most of its muscles being flaccid and relaxed. Diplopia is the most marked functional result. In consequence, however, of its close proximity to the fourth, fifth, and sixth nerves in the walls of the cavernous sinus and sphenoidal fissure, symptoms referable to these trunks are often associated with the above, as also venous congestion of the eye and orbit from pressure on the sinus. Should the eyeball be totally immobilized from paralysis of all its muscles without venous congestion, the condition is known as 'ophthalmoplegia externa,' and is always due to central disease affecting the floor of the third ventricle, and probably of syphilitic or tabetic origin. The **Treatment** in most cases consists in the administration of mercury and iodide of potassium.

Paralysis of the **Fourth Nerve** (*Pathetic*), which supplies the superior oblique muscle, results in defective movement of the eyeball downwards and outwards, with diplopia on attempting to look down.

The **Fifth or Trigeminal Nerve** is occasionally torn in head injuries, giving rise to anæsthesia, with perhaps ulceration of the cornea; but such cases are exceedingly rare. Much more common is the affection known as *trigeminal neuralgia*, or tic-douloureux, which occurs most often in old people, particularly women. It is to be distinguished from the simpler forms of neuralgia due to some local irritation or general weakness by the paroxysmal character and violence of the pain; hence the term 'epileptiform tic' has been applied to it, and not inaptly represents its terrible nature. As a rule it commences in the infra-orbital or inferior dental branches, radiating thence to all the other divisions of the nerve. The paroxysms are not very frequent at first, but they increase both in number, duration, and severity,

and may be induced by any peripheral stimulus, a sudden noise, a draught of air, etc., until at last the patient, utterly prostrate, either becomes a morphia habitué or may even attempt suicide. The condition is often influenced considerably by the general health, and intermissions of varying length occur. The attacks are accompanied by twitching of the muscles of the face, and even of the neck; also by unilateral sweating and hyperæmia of the head, which becomes so tender and hypersensitive that the patient cannot brush the hair or wash the face on the affected side. Lachrymation is a marked feature during the attacks, and the secretion of saliva or of nasal mucus may be increased.

Trigeminal Neuralgia.—The **Cause** is unknown; in a few cases tumours of the ganglion itself may be caused by gummata in the region of the ganglion. Very occasionally aneurisms in the middle fossa may press on the ganglion; but in the great majority nothing abnormal can be found either in the ganglion or its branches.

Treatment.—There can be no dogmatic advice with regard to patients suffering from trigeminal neuralgia as to which form of treatment is the best; every patient must be considered independently. If the patient is in good health, apart from the neuralgia, then open operation and division of the sensory root is undoubtedly the treatment. If, on the other hand, the patient is aged and debilitated, alcohol injection is the obvious treatment.

Even in those cases where open division of the sensory root is contemplated, it is a sound procedure to inject the Gasserian ganglion prior to the operation, so that the patient may experience the numbness of the face which is permanent after the division of the sensory root, but temporary after alcohol injections. This is most necessary, as quite often patients, when cured of their neuralgia, complain bitterly of the numbness or 'deadness' of the face, and even go so far as to blame the surgeon for not telling them before the operation that such a condition would ensue.

Alcohol Injections.—There is only one way in which the technique of alcohol injections into the second and third divisions of the fifth nerve or into the Gasserian ganglion itself can be perfected, and that is by repeated attempts on the cadaver. Not until the surgeon is quite familiar with the method on the cadaver should he attempt the injection on the living patient. In the past, failure of injections to cure the pain has quite often been due to the fact that they have been carried out by inexperienced individuals.

The equipment required consists of a 2 c.c. Record syringe and a set of needles, as shown in Fig. 167. There are many varieties of needles, but they should be made of stainless steel and vary from 3 to 5 inches in length and should be graduated in centimetres. Some 1 per cent. solution of novocain and some 90 per cent. alcohol complete the requirements. Although some authorities advise a general anæsthetic for the injections, this should always be avoided, as it is very important to have the co-operation of the patient.

Injection of the Maxillary Nerve.—There is only one real method for injecting this nerve, which should always be done at the foramen

Drawing showing the Position of the Needle in the Foramen Ovale: Anterior Approach.

rotundum, and that is the one devised by Dr. Harris, of St. Mary's Hospital.

The patient is seated on a chair, while the head is kept still by a nurse, who holds it from behind. The skin of the face is painted with some $2\frac{1}{2}$ per cent. solution of iodine in absolute alcohol. Two points on the skin of the cheek require to be marked out, the first being the point where the anterior border of the coronoid process forms an angle with the malar bone. The second point is the frontal process of the malar bone where it bends sharply upwards. These two points are joined by a straight line.

Some 1 per cent. novocain is injected with a hypodermic needle into the lower of the two points marked out. The injecting needle is now taken in the right hand with the index finger pressed against the barrel of the needle to steady it. The needle is gently pressed through the cheek in an inward and upward direction at an angle of about forty degrees above the horizontal, taking care to keep the line of the needle in the direction of the line drawn on the surface of the cheek. The point of the needle will pass behind the maxilla and enter the pterygo-

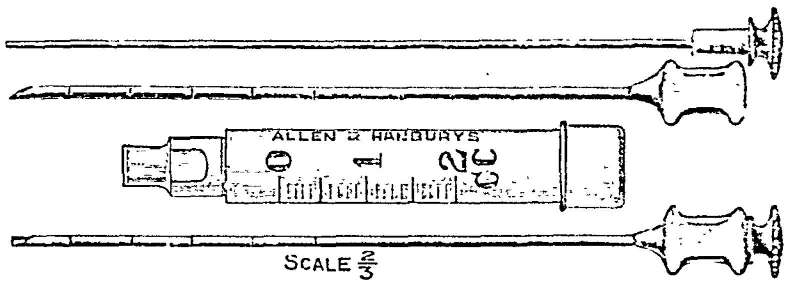


FIG. 167.—SYRINGE AND NEEDLES USED FOR ALCOHOL INJECTION.

maxillary fissure. The superior maxillary nerve is encountered at the foramen rotundum, usually at a depth of 2 inches. The patient complains of pain which is referred to the side of the nose and upper lip wherever the nerve is punctured by the needle. It is a good plan to inject two or three drops of novocain solution, and after half a minute there should be some slight anæsthesia in the peripheral distribution of the second division of the fifth nerve on the face. If this occurs, then five or six drops of 90 per cent. alcohol are slowly injected, producing, to begin with, a burning sensation in the cheek, lip, and nose, followed by anæsthesia. If the novocain were not injected previous to the injection of alcohol, the patient would suffer intolerable pain.

Injection of the Mandibular Nerve.—There are two routes available for the injection of this nerve, both having their advocates and both giving good results. There is the horizontal lateral approach, which has been perfected by Harris; and an ascending anterior approach, which is advocated by Hartel. Personally, we have always used the anterior approach for a number of years, and it gives excellent results (Plate VI.).

Lateral Route.—In this route the needle passes beneath the zygoma and through the sigmoid notch of the mandible. It is therefore important to mark out the under surface of the zygoma, which can readily be done, as it is subcutaneous. The lower border of the sigmoid notch can be demarcated by a line drawn from the incisura notch of the ear to the lower border of the ala of the nose. The vertical plane, which, passing at right angles to the side of the cheek, cuts the foramen ovale, can be marked out quite easily, as it lies 1 inch in front of the middle of the external auditory meatus. The needle is introduced at the point where the vertical line intersects the line marking the sigmoid notch, and some novocain is injected. The needle is then pushed inwards and slightly upwards until the foramen ovale is reached, which is usually at a depth of 5 cm. The patient often complains of a stabbing pain in the lower lip and chin; a few drops of novocain are injected, and if anæsthesia develops in the area of distribution of the nerve, 1 c.c. of 90 per cent. alcohol is slowly injected. If the needle is directed too far backwards, its point may enter the Eustachian tube and the patient will complain of pain in the ear; while, if the needle is inserted too low, the pharynx may be perforated, causing pain in the throat. In either case it is essential that the needle should be withdrawn and another attempt made to enter the foramen ovale. As quite a number of patients who suffer from trigeminal neuralgia are edentulous, there may be some difficulty in traversing the sigmoid notch; in these cases, if the mouth is fixed in an open position by means of a dental prop, the difficulty is easily overcome.

Anterior Route.—This is the longer of the two routes, the foramen ovale lying about 8·5 cm. from the skin. The foramen is approached from a better angle from below and in front, and is, in my opinion a more satisfactory method. The patient is seated on a chair facing the surgeon, while a nurse steadies the back of the head. After some iodine solution has been applied to the cheek, a point is marked out 2 cm. external to the angle of the mouth; this point is then infiltrated with some novocain solution. A 5-inch needle is introduced at the point selected and passed in an upward, backward, and inward direction so that it is superficial to the buccinator muscle but deep to the mandible.

The needle can be guided by a finger introduced into the patient's mouth. It is made to pass through the external pterygoid muscle and into the nerve as it passes out of the foramen ovale. Quite frequently the nerve is 'hit off' at the first attempt, but at other times the point of the needle strikes the smooth intratemporal crest of the temporal bone. In such cases it is necessary to manipulate carefully backwards so as to enter the foramen ovale. It is quite possible to enter the Eustachian tube or pharynx when the needle is introduced too horizontally or too medially; in either case the needle must be withdrawn and another attempt made. It is very important not to introduce the needle too deeply, as it may pass into the Gasserian ganglion and through into the subarachnoid space; in such a case cerebro-spinal fluid will drip from the needle when the stylet is withdrawn. On no account should any alcohol be injected in such a

case, or paralysis of the sixth, seventh, and eighth cranial nerves may occur.

On very rare occasions the internal maxillary artery may be injured and a hæmatoma may develop; this, however, calls for no treatment. As soon as the nerve is reached it is injected in a similar manner to that described in the lateral method of approach.

Injection of the Gasserian Ganglion.—Although the ganglion may be injected by a lateral or an anterior route, the latter is far more reliable and satisfactory, and is the only one described here. The method is in every way similar to that used for injecting the mandibular nerve from the front, except that the needle is introduced a further centimetre when the nerve is reached at the foramen ovale. It is very important that no alcohol should reach the subarachnoid space (*vide supra*).

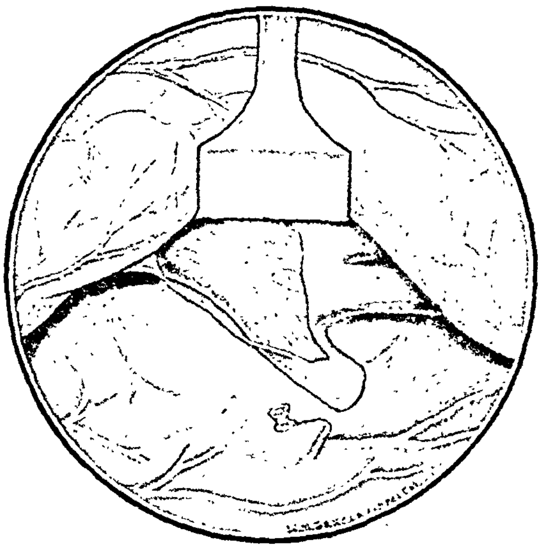


FIG. 168.—DRAWING SHOWING EXPOSURE OF GASSERIAN GANGLION.
The visceral layer of dura mater has been raised. The ligatured middle meningeal artery can be seen at the foramen spinosum.

After injection of the ganglion has produced anæsthesia of all three divisions of the trigeminal nerve, neuropathic keratitis may occur. It is, therefore, a wise precaution to stitch the upper and lower lids together. The muscles of mastication are frequently paralyzed after alcohol injection into the ganglion, but motor recovery is generally the rule after two or three months. In rare cases, where the neuralgia is bilateral, it is important not to inject the second side until the masticatory muscles on the first side have fully recovered their tone, or mastication will be impossible. It is a very wise precaution to X-ray the skull in all cases where injection into the ganglion is contemplated, so as to see the shape, size, and position of the foramen ovale.

Division of the Sensory Root.—This operation, which is associated with the name of Frazier, has replaced all operations on the Gasserian

ganglion, as it gives such excellent results. General anæsthesia combined with local novocain infiltration into the area of operation is

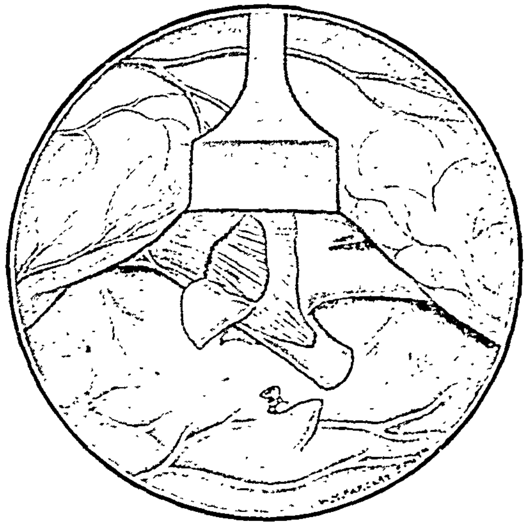


FIG. 169.—EXPOSURE OF SENSORY ROOT.
A small flap of arachnoid has been raised up, exposing the fan-shaped sensory root.

preferred to local anæsthesia by itself. The patient should be operated upon in a dental chair so as to maintain the head in a vertical position;

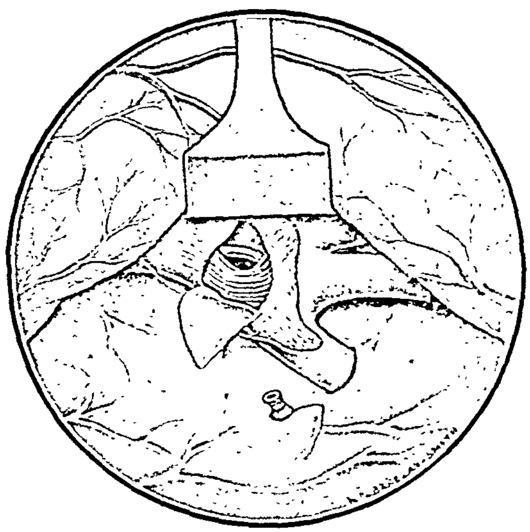


FIG. 170.—EXPOSURE OF SENSORY ROOT.
The fibres of the sensory root have been drawn outwards, thus exposing the motor root, which is on its deep aspect.

by so doing, venous bleeding is reduced, and escape of fluid from the somewhat small and dependent operation area is greatly facilitated.

Some castor oil drops should be instilled into the eye on the affected side, and a piece of gutta-percha tissue should be used to cover it.

The scalp in the region of the temporal fossa should be infiltrated with ½ per cent. novocain. An incision 3 inches in length is made in front of the ear, extending over the zygoma.

The vertical incision has replaced all the old-fashioned horseshoe flaps, as it gives quite adequate exposure (*Fig.* 171). The temporal fascia and underlying muscle are incised in the same line as the skin incision, and retracted laterally. The periosteum is incised and detached from the temporal bone by means of a periosteal elevator. A burr-hole is then made through the temporal bone. This opening is then enlarged with bone forceps until it is about 2 inches in diameter (Fig. 172).

The opening should extend downwards as far as the infratemporal crest. The dura mater is carefully separated from the base of the skull and a blunt retractor is inserted to keep the brain away from the middle fossa. The middle meningeal artery is exposed as it emerges into the middle fossa through the foramen spinosum; it is either tied

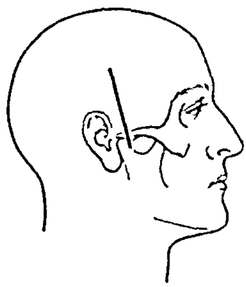


Fig. 171.—Incision for Exposure of the Sensory Root of the Fifth Nerve.

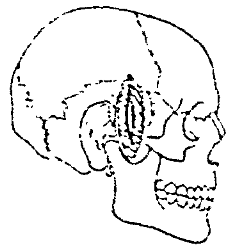


Fig. 172.—The Exposure of the Gasserian Ganglia.

with two ligatures or coagulated with the diathermy current. In some cases the foramen spinosum may be plugged with a small spigot of whitewood, if other methods fail to stop the bleeding.

The dura mater is still further stripped up until the third division of the fifth nerve and the edge of the foramen ovale are exposed. The sheath of the nerve is incised and gently pushed upwards and backwards, and in so doing the Gasserian ganglion is exposed (Fig. 168).

As a general rule, if the area is well illuminated, the sensory root can be seen through the arachnoid sheath. A small flap of arachnoid sheath is now turned downwards, exposing the fan-shaped fibres of the sensory root (Fig. 169).

By means of a small blunt hook the fibres of the sensory root are drawn outwards, exposing the motor root, which can generally be recognized without difficulty, as it is a small, compact structure (Fig. 170).

The sensory root is divided just behind the ganglion.

After removal of the retractor the brain falls back into its place, and the temporal muscle can be sutured with a few interrupted catgut

sutures. The skin is closed with a few interrupted silkworm gut sutures. A watch-glass is placed over the eye and secured by a piece of strapping. The patient should be kept in bed for a week, and may then be discharged. If any signs of keratitis occur, it is advisable

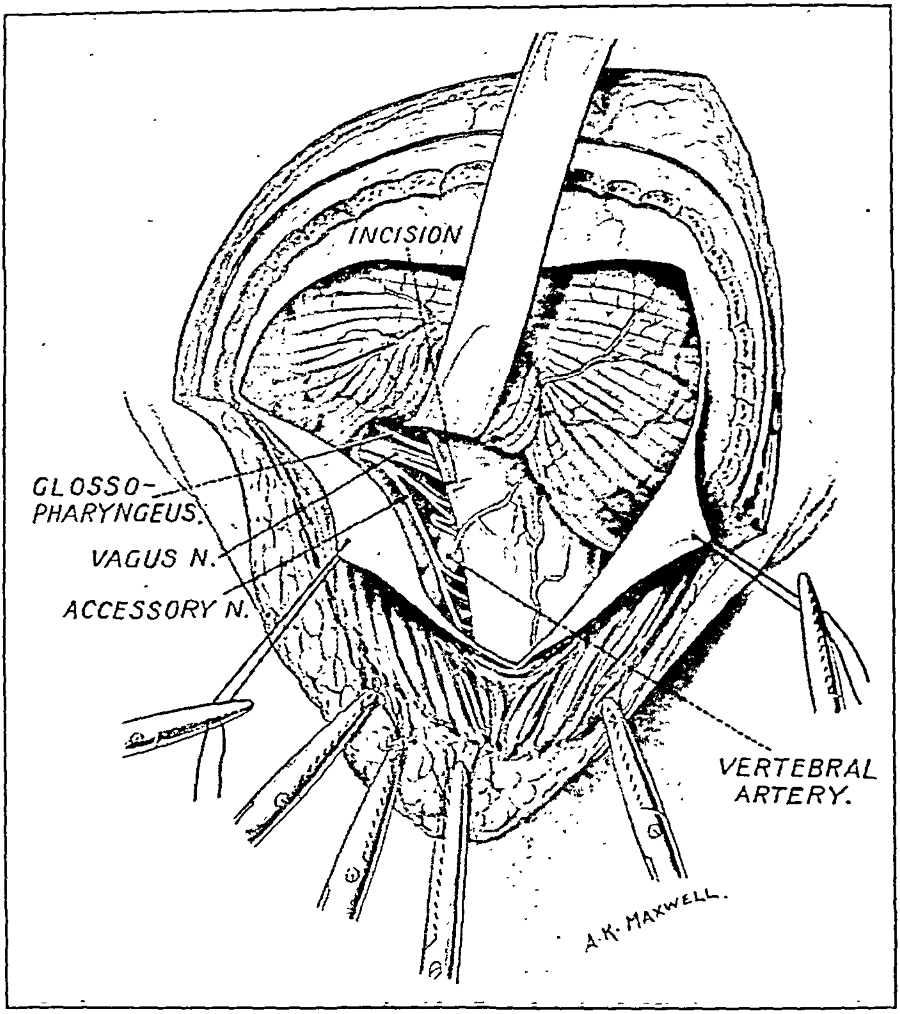


FIG. 173.—OPERATION VIEW SHOWING THE SITE FOR INTRAMEDULLARY TRACTOTOMY.

to stitch the upper and lower lids together; but this rarely occurs if the patient is instructed not to rub the eye and to keep out of dusty places.

Fractional Division of the Sensory Root.—This operation consists in dividing the lower and outer two-thirds. The resulting anæsthesia affects the lower two-thirds of the face and half the cornea. In some cases the line of anæsthesia runs strictly through the pupil, the lower half of the cornea being insensitive, the upper normal. Probably the safest way of performing fractional division is to expose the sensory

ɔot, as described above, and then cut through the root from without ıwards with long, fine scissors. The results of this operation are ıperior to those of complete section because there are no dangers which ıay result from an insensitive cornea.

Intramedullary Tractotomy.—By means of a cerebellar approach jögvist, in 1938, devised an operation in which he was able to divide ıe pain fibres in the descending limb of the trigeminal tract by an ıcision through the posterolateral aspect of the medulla oblongata ?ig. 173) and spare the sensation of touch so that the face did not ːmain unpleasantly numb. Reported cases in this country prove ıe value of this operation.

The advantages of the operation are that the face is not denervated ɔmpletely; analgesia is greatest in the forehead, and the muscles

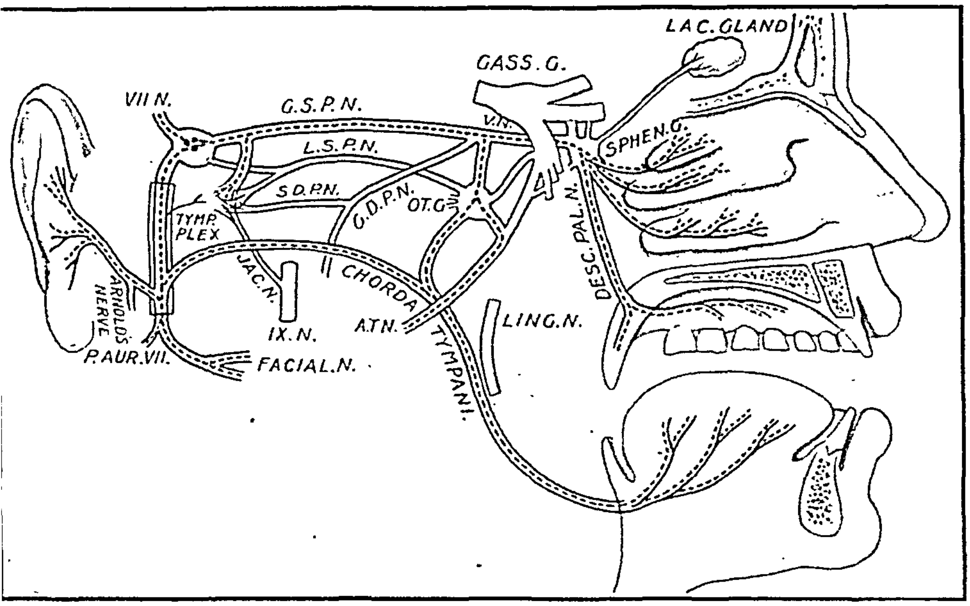


FIG. 174.—CONNECTIONS OF THE FACIAL NERVE.

: mastication are never paralyzed, a very important consideration bilateral cases. Moreover, the great superficial petrosal nerve is .r from the site of operation and therefore the danger of a 'dry' ,e is avoided.

The **Sixth Nerve** may be torn or compressed, either in its intra-ʻanial course along the inner wall of the cavernous sinus, or as it ısses through the sphenoidal fissure, or in the orbit, as a result of ənetrating wounds or blows. Its division causes paralysis of the ɛternal rectus and consequent internal strabismus.

The **Seventh or Facial Nerve** has a very complicated course and .any connections (Fig. 174); it may be *paralyzed* from a great variety : causes, which may be described under the following headings:

(*a*) *Intracranial Lesions.*—If simply *cortical*, as from pressure, ɛmorrhage, degeneration, etc., a limited portion of the opposite side : the face is usually involved. If *subcortical*, or in the corona radiata

or corpus striatum, as from hæmorrhage, or softening due to carotid thrombosis or embolus, the paralysis appears on the opposite side, together with hemiplegia, but only the lower half of the face is affected, the associated movements of the eyelids being left. If the lesion is situated in the *pons*, the deep facial centres may be implicated, and then paralysis with rapid atrophy of the facial muscles ensues on the same side as the lesion, together with loss of power of the opposite arm and leg (crossed paralysis). If the *root* of the nerve between the centres and the internal auditory meatus is involved, the whole of the same side of the face is paralyzed, accompanied, as a rule, by deafness.

(*b*) *Cranial Lesions.*—There are two not uncommon causes grouped under this heading, *viz.* (i.) fracture of the base of the skull, involving the petrous bone, the paralysis supervening either immediately after the injury from laceration, a rare phenomenon, or some weeks later from implication in organizing blood-clot or callus, the usual cause; or (ii.) as a complication of chronic otorrhœa, due to compression or inflammation of the nerve in the aqueductus Fallopii, or its injury or division during a mastoid operation. In all these the palsy is complete on the side affected, and owing to the communication of the facial with the petrosal nerves in this part of its course, there may be unilateral drooping of the velum palati, the uvula being deflected towards the sound side.

(*c*) *Extracranial lesions* from injury, inflammation from exposure to cold, or the pressure of a tumour, *e.g.* malignant disease of the parotid. This variety has been called ' Bell's palsy," and is usually characterized by the whole side of the face being affected, but without implication of the palate or uvula.

The general **Signs** of facial paralysis (Fig. 175) are as follows: The side of the face is immobile and expressionless, all the natural folds and wrinkles being lost; the eye cannot be completely closed, and on attempting to do so the eyeball is usually seen to roll upwards and outwards (Fig. 176); ulceration, and even perforation, of the cornea may result from this exposure. From the drooping and relaxation of the lower eyelid, the apposition of the punctum lachrymale to the conjunctiva is imperfect, and thus tears escape over the face (epiphora), a condition aggravated by the loss of the suction-like action of the lachrymal sac, owing to the associated paralysis of the tendo oculi and tensor tarsi. On attempting to move the face, as in laughing or showing the teeth, the muscles on the non-paralyzed side are alone contracted, and marked asymmetry results from the drawing over of the opposite side. The lips cannot be closed firmly, and hence whistling and such-like actions are prevented. Food collects between the cheek and the teeth, owing to paralysis of the buccinator, and the patient after a meal has to clear out the débris with a spoon or his fingers.

The **Treatment** of facial paralysis should, if possible, be directed to its cause. Accidental division of its extracranial portion must be followed by suture, either immediate or secondary. When due to the pressure of a tumour, it may be possible to free it by operation. In cases caused by cold, medical treatment, including massage and

electricity, must be relied on, and will usually prove effective. When the paralysis persists, and especially if due to some cranial lesions which cannot be reached, **nerve-anastomosis** may be undertaken, one-half of the hypoglossal nerve being united to the divided peripheral end of the facial nerve. The results hitherto obtained have been moderate; facial movements slowly return, but are first elicited by and accompanied with movement of the tongue; in time, however, they become more independent, but are rarely quite free. However, the operation gives a certain amount of muscular power, and may remove the facial asymmetry.

In cases where the seventh nerve has been accidentally divided during the course of a mastoid operation, nerve grafting should be

FIG. 175.—RIGHT FACIAL NERVE PARALYSIS.

Note absence of wrinkles on the right side of the face.

FIG. 176.—LEFT FACIAL NERVE PARALYSIS.

The patient is closing his eyes. Note the contrast of the two eyes.

tried in an attempt to restore function. Several methods have been suggested, amongst them the anastomosing of the distal cut end of the facial nerve to the spinal accessory or hypoglossal nerve. None of these methods has been very satisfactory, but recently Ballance and Duel have evolved a technique for restoring the anatomical and physiological continuity of the nerve by means of a homogeneous prepared nerve graft. This graft is usually taken from the intermediate cutaneous nerve of the thigh, and in order to allow for degeneration and absorption of the unrequired elements of the nerve graft it is divided and left *in situ* for two weeks before it is required. When the facial nerve is exposed and its bony canal and site of injury ascertained, the divided ends of the nerve are carefully trimmed and freed of any granulations or fibrous tissue. A piece of the prepared graft

of appropriate length is placed in position so as to bridge the gap, and care is taken to ensure accurate approximation of the graft with the cut ends. The operation area is covered with a piece of thin dental gold foil, which is left undisturbed for some weeks. A bridge of as large a gap as 25 mm. has been attended with success.

The ultimate results in skilled hands have been excellent, and this is undoubtedly the procedure of choice in dealing with injuries to the facial nerve.

It has been recently shown by Bentley and Hill that in experimental nerve grafting on cats it is immaterial whether the fresh or prepared nerve is used for the grafting.

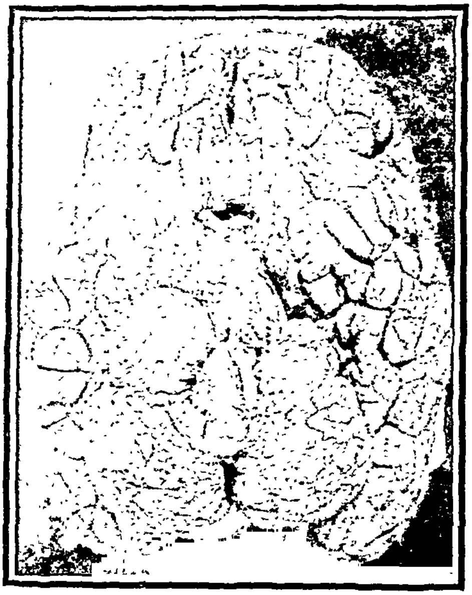


Fig. 177.—Photograph of Under Surface of Brain, showing Bilateral Acoustic Nerve Tumours. (Dr. Minski's Case.)

Facial Tic (or histrionic spasm) consists of a clonic contraction of the facial muscles, due to an irritative lesion in the cortex or pons, or the reflex result of some affection of the nasal mucous membrane or of the teeth. The condition causes great discomfort to the patient, and may involve the whole side of the face, or merely one part of it, such as the orbicularis oculi. **Treatment** consists in the administration of nerve tonics or antispasmodics, and in the removal of sources of reflex irritation. The only operative procedure of any value is the injection with alcohol of the nerve at the stylo-mastoid foramen, and if this fails section of the facial nerve and facio-hypoglossal anastomosis.

Operation.—The facial nerve can be exposed immediately below the ear, its position being indicated by a horizontal line drawn from the middle of the anterior border of the mastoid process, and usually corresponding to the point where the mastoid meets the lobule of the ear. The incision extends from just behind the external meatus along the anterior border of the sterno-mastoid muscle to the level of the angle of the jaw. The parotid gland is separated from the muscle, and both are well retracted, exposing by this means the posterior belly of the digastric. The facial nerve is found above this, running directly forwards from the centre of the mastoid process. The great auricular nerve is divided in the superficial incision, and the posterior auricular vessels will require a ligature. The internal jugular vein is close to the posterior margin of the wound. The operation is a deep one, and by no means easy in a patient with a thick neck.

The **Auditory Nerve** may be injured in fractures of the base of

the skull, either one or both sides being involved. Incurable deafness usually results, often associated with facial palsy.

Acoustic Nerve Tumours occur in middle age, and grow from the neurilemmal sheath of the auditory nerve at the internal auditory meatus. The tumour may reach a large size (Fig. 177) before a correct diagnosis is reached, and may erode and enlarge the internal auditory meatus, and this may be seen in a skiagram.

These tumours quite often produce a characteristic syndrome in which deafness, tinnitus, vertigo, and paræsthesia of the fifth nerve play a part. As the tumour grows there are signs of a rise in the intracranial tension and of cerebellar involvement.

Treatment consists of the removal of the tumour through a cerebellar approach (see Chapter XXVII.).

It is a little doubtful what effect would be produced by injury of the **Glosso-pharyngeal Nerve,** but in one case in which it was supposed to be compressed the patient suffered from difficulty in swallowing and speaking, together with persistent ulceration of the tongue; death resulted from œdema of the glottis.

Glosso-pharyngeal Neuralgia.—Fortunately this is a rare disease which may be mistaken for trigeminal neuralgia. The pain is that of the fifth nerve, is spasmodic, but is localized to the ear and the fauces, and does not spread to the face.

Treatment consists in resection of the nerve through an incision along the upper border of the sterno-mastoid muscle. An alternative route is to expose the nerve in the posterior fossa of the skull by means of a cerebellar operation.

A severe crushing injury to the **Pneumogastric Nerve** may prove rapidly fatal from heart failure or pulmonary congestion, but less serious lesions result in palpitation, vomiting, and a sense of suffocation; such phenomena sometimes manifest themselves after head injuries, especially fractures involving the posterior fossa, and indicate that the jugular foramen has been encroached on. The nerve is also exposed to injury in operations about the neck, *e.g.* ligature of the carotid, or removal of tuberculous or malignant glands. Irritation causes vomiting, coughing, or perhaps a temporary inhibition of the heart's action; one-sided division sometimes does comparatively little immediate harm, but if both nerves are divided, death results from laryngeal paralysis or from such complications as œdema or congestion of the lungs.

The effect on the larynx of these lesions is described elsewhere, but one may note here that in the *early* stages compression paralysis of the recurrent laryngeal nerve, as by an aneurism, affects the abductor muscle (crico-arytenoideus posticus), the result being that the cord involved is approximated to the middle line, and then the voice is not impaired, although dyspnœa is present. At a *later* stage compression paralysis corresponds to the phenomena produced by complete section of the nerve, as in an operation for goitre, *viz.* the cord lies in the cadaveric position, *i.e.* half-way between its position in phonation and deep inspiration; in this, breathing is unimpaired, but the voice is husky.

The **Spinal Accessory Nerve** may be irritated, either at its exit from the skull by a fracture running through the jugular foramen, or in its peripheral course by inflamed lymphatic glands, etc. It is occasionally divided in operations for the removal of tuberculous or malignant glands, and in children this may cause serious deformity from tilting of the scapula, especially if the branches of the cervical plexus supplying the trapezius are also severed. Clonic spasm of the sterno-mastoid and trapezius is generally due to central changes, and for this form of spasmodic torticollis stretching or division of the spinal accessory nerve has been employed, but is of little or no value.

FIG. 178.—TONGUE IN PARALYSIS OF RIGHT HYPOGLOSSAL NERVE.

Operation.—The nerve runs downwards and backwards at right angles to the centre of a line passing from the angle of the jaw to the apex of the mastoid process; it enters the deep aspect of the sterno-mastoid about 3 inches below that spot. An incision is made along the anterior border of the sterno-mastoid, reaching from the ear to the cornu of the hyoid bone. The fascia is divided and the muscle drawn backwards to expose the posterior belly of the digastric, from under the lower border of which the nerve emerges, passing first in front of and then below the transverse process of the atlas, which can be readily felt.

The **Hypoglossal Nerve** may be accidentally divided *in an operation* for the removal of tuberculous or cancerous glands, or it may be compressed by an aneurism of the external carotid, or invaded by a new growth. It is also affected to a certain extent in some forms of hemiplegia. Unilateral paralysis or weakness of the tongue results (Fig. 178), the organ, when protruded, being directed towards the paralyzed side.

The Spinal Nerves.

The nerves constituting the **Cervical Plexus** are exposed to injury either from blows, dislocations of the cervical spine, penetrating wounds, or during operations. No very serious results follow, except in the case of the **Phrenic Nerve,** bilateral division of which may cause instant death by paralysis of the diaphragm. Unilateral avulsion from the neck has been employed as a therapeutic agent in order to paralyze one half of the diaphragm, and thereby secure rest to the lung in cases of bronchiectasis or tuberculous disease affecting the lower lobe. It has proved distinctly beneficial in some cases. Irritation of the nerve gives rise to spasmodic cough or hiccough.

The **Brachial Plexus** may be injured in gunshot wounds, or occasionally divided by *cuts or stabs* in the lower part of the posterior triangle, and the accident will be characterized by the motor or sensory phenomena corresponding to the particular nerves involved; the lower nerve-trunks are more often involved than the upper.

Tears or contusions of the plexus, a more common accident, may be complete or partial, and result from injuries in which the arm is dragged suddenly upwards, as when in falling a person clutches at some projecting body, or from forcible depression of the shoulder in a fall whilst the head is driven towards the opposite side, the nerve-roots being thereby wrenched from their attachments or the nerve-trunks compressed by the clavicle against the first rib. Long-continued hyper-extension and abduction of the arm, as during an operation in the Trendelenburg position, also cause undue traction upon the roots of the plexus, especially of the fifth and sixth nerves. A fracture of the clavicle by direct violence may result in injury of the plexus, and the pressure of a cervical rib may affect the inner cord. Dislocation of the head of the humerus into the axilla, or the attempts to reduce it, may also be responsible for injuries, especially to the inner cord. The lesions consist either of a complete rupture of the nerve-trunks, or of a partial rupture with hæmorrhage into and around the sheaths. If the sheaths remain untorn, repair is usually established after a time; but where a complete laceration has occurred, much cicatricial tissue is likely to form, and unless operation is undertaken, repair is improbable.

In infants a *brachial birth-palsy* is observed, due to forcible stretching and tearing of the roots of the plexus. It is caused by overstretching of the head during delivery, and may occur equally in vertex or breech presentations; it is usually unilateral, and affects more frequently the left arm. At first supraclavicular tenderness may be noted, and then the loss of power of the arm becomes manifest; this may affect the whole arm to begin with, but with suitable treatment the condition usually limits itself either to the upper arm or Erb-Duchenne type (80 per cent.), or to the lower arm or Klumpke type (20 per cent.).

Symptoms.—If all the **nerve-roots** are involved, the whole arm is paralyzed, and lies flaccid and anæsthetic by the patient's side. Sensation is alone present down the inner side of the arm as far as the elbow (intercosto-humeral nerve), and for a more limited portion on the outer side. Paralysis often involves the pectoralis and scapular muscles, but the rhomboids and serratus magnus retain their nerve-supply. Oculo-pupillary changes may be manifested if sympathetic fibres are involved in the injury; the pupil is contracted, and mydriasis defective on excluding the light.

The **upper-arm type** is generally due to tearing or stretching of the fifth and sixth cervical nerves, and corresponds to what is known as the *Erb-Duchenne paralysis*. There is loss of power of the deltoid, spinati, biceps, brachialis anticus, and supinator longus muscles, as well as the clavicular fibres of the pectoralis major, the latissimus dorsi, teres major, rhomboids, and subscapularis. Sensation is usually

but little involved, as the area supplied by the fifth and sixth roots is not extensive (Fig. 187). The result on the limb is very characteristic. The arm lies close to the side and cannot be abducted or rotated, but in children fixed internal rotation may become evident later on. The forearm is extended and in a position of pronation, all supination being lost, and the elbow cannot be flexed. Usually the movements of the hand and wrist are unimpaired, but occasionally the wrist extensors are paretic.

The **lower-arm type** is caused by injuries to the eighth cervical and first dorsal nerves, the resulting paralysis being described as of the *Klumpke type.* The flexors of the wrist and fingers (Cviii) and the intrinsic muscles of the hand (Di) are paralyzed, and a claw-hand (Fig. 183) results. Anæsthesia along the distribution of the ulnar nerve becomes evident.

Lesions of the cords of the brachial plexus below the clavicle are uncommon, and it is unnecessary to describe their effects, which are controlled by their well-known anatomical distribution.

Treatment necessarily varies with the situation and degree of injury, but follows that for lesions of the peripheral nerves.

Aseptic cuts and stabs are of course explored, and divided nerves secured, if possible, by primary suture.

In infected lesions, such as the majority of gunshot wounds, suture must be delayed until the infection has disappeared and the wound healed, and in the meantime massage and electricity are employed to maintain the nutrition of the muscles.

Obvious causes of pressure, such as the depressed fragments of a broken clavicle, or the callus resulting therefrom, must be removed, and a cervical rib, if causing symptoms, should be excised.

In traumatic cases without open wound, and this includes the birth-palsies, the arm is placed at right angles to the trunk and kept at rest, whilst local pain and tenderness are relieved by fomentations. The position is important in that it limits tension on the nerve-ends and approximates them as much as possible. After a short while passive movements are employed to keep the joints supple, and massage and galvanism are commenced to maintain the tone of the muscles. Power and sensation gradually reappear in those regions where the nerve-supply has not been severed, but the paralysis persists in the muscles supplied by the divided nerves, and the reaction of degeneration appears in due course; a thickened cicatricial mass can usually be felt at the site of the lesion. Under these circumstances operation is desirable in order to secure the restoration of continuity of the injured nerve-trunks.

The brachial plexus is exposed through an incision running downwards along the posterior border of the sterno-mastoid and prolonged downwards, if need be, across the clavicle. The scalenus anticus is defined, and the nerves are found emerging from between it and the scalenus medius; cicatricial tissue is removed, and the nerve-ends are freshened and sutured together. In cases involving the lower section of the plexus, it may be necessary to divide the clavicle in order to expose the affected portion of the nerves. The results of operations

of this type have been on the whole encouraging, if they are not delayed too long. In neglected cases of birth-palsy of the Erb-Duchenne type it is sometimes necessary to free the shoulder-joint, which has become fixed; division of the tendon of the subscapularis is then useful so as to permit the arm to be raised from the side.

Occasionally, the injury is more limited, as when a blow on the back of the neck leads to paralysis of the serratus magnus and rhomboids, and to the subsequent development of a 'winged scapula'; it may also result from cold or toxæmia.

The **Circumflex Nerve** is liable to injury from its exposed position, winding round the outer side of the neck of the humerus about a finger's breadth above the middle of the deltoid. Blows upon the shoulder may in this way cause paralysis; it is sometimes torn or compressed in fractures of the surgical neck of the humerus, or in dislocation of the shoulder, or it may be impacted in the callus arising from the former injury. It is involved more often in crutch palsy. Paralysis of the deltoid and teres minor follows, evidenced by inability to raise the arm from the side, whilst the wasting of the former muscle causes undue prominence of the acromion. There may be temporary anæsthesia over the posterior fold of the axilla, but this does not last long. **Treatment.**—If the cause of the pressure is removed, massage and electricity are usually sufficient to determine restoration of function, and operative measures are seldom required. It must be remembered that in the early stages of re-educational exercises the weight of the arm must be eliminated by supporting it on a table.

The **Musculo-spiral Nerve** may be injured in fractures and dislocations of the upper end of the humerus, but is more likely to be damaged in fractures involving the musculo-spiral groove. It is implicated with or without other nerves in crutch palsy, or by lying asleep with the arm across the edge of a chair or table, as sometimes occurs in drunken people ('Saturday-night paralysis'). It is not unknown after operations when the outstretched arm has rested on the edge of the table, or when the Trendelenburg position has been adopted and the arms have been kept above the patient's head, the upper end of the humerus pressing against the brachial plexus. In this position the arms should not be raised to more than a right angle with the trunk.

Total division of the nerve causes the following symptoms:

A. Anæsthesia. If the nerve is divided in the upper third of the arm, *i.e.* above the origin of its external cutaneous branch, there is loss of both epicritic and protopathic sensation over the radial half of the dorsum of the hand, of the epicritic a little more than of the protopathic. Section of the radial nerve in the upper third of the forearm causes no loss of sensation, which is supplied to the back of the hand by the external cutaneous of the brachial plexus; but section in the lower third causes a limited loss of epicritic sense over the back of the thumb.

B. Paralysis of the following groups of muscles:

(i.) Of the extensor of the forearm (triceps); hence the forearm can only be extended by its own weight.

(ii.) Of the long and short supinators; hence the hand is pronated, the only supinator remaining being the biceps.

(iii.) Of the radial and ulnar extensors of the wrist; hence wrist-drop (Fig. 179), a condition also present in certain lesions of toxic or central origin, *e.g.* lead palsy.

(iv.) Of the extensors of the fingers and thumb, which either hang limp and motionless, or may be bent up into the palm from the unopposed action of the flexor muscles. If, however, the wrist and proximal phalanges are supported and extended, the terminal phalanges can be straightened by the action of the interossei and lumbricales.

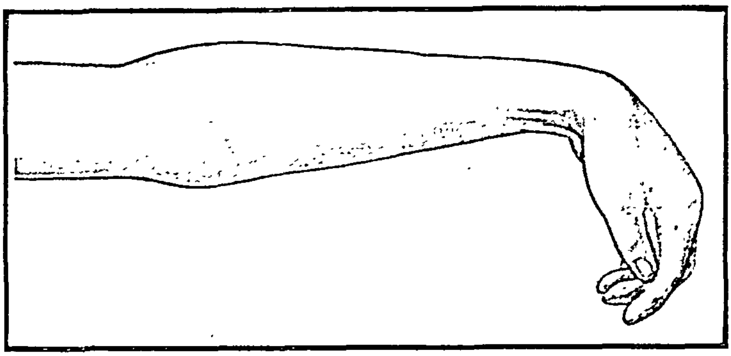


FIG 179.—WRIST-DROP FROM PARALYSIS OF THE MUSCULO-SPIRAL NERVE.

Treatment.—In all cases of paralysis of the musculo-spiral nerve, the first essential is to prevent stretching of the muscles and tendons on the extensor aspect of the wrist by fixing the hand in a position of slight hyper-extension by the use of a 'cock-up' splint (Fig. 115). The forearm is massaged and the muscles treated by electricity, whilst the question whether or not an operation is required is being considered, or whilst the wound, if septic, is being treated and healed. When once it is decided, however, that the nerve has been divided as indicated by absence of improvement, the sooner operative treatment is undertaken the better. For general details, see p. 390. Where the nerve is impacted in the callus arising from a fracture of the middle of the shaft of the humerus, it is often best to expose it by a median incision down the back of the arm, splitting the triceps, the centre of the wound being opposite the insertion of the deltoid. Where there is much loss of substance, the nerve must be freed widely above and below so as to increase the chance of approximating the ends; in a few cases a portion of the humerus has been excised in order to shorten the limb sufficiently. The prognosis of this operation is on the whole good.

In cases where operation has failed, or where the posterior interosseous nerve has been gravely damaged and cannot be repaired by operation, the condition of wrist-drop may be improved by grafting the tendons of the flexor carpi ulnaris and the flexor carpi radialis into the tendons of the extensors of the thumb and fingers, and the detached tendon of the pronator radii teres into the lower ends of the divided radial extensors of the carpus. A longitudinal incision along the radial border of the middle of the forearm suffices for the latter operation; a horseshoe-shaped incision with the convexity downwards, reaching to the back of the carpus, and with the straight sides over the radial and ulnar borders of the forearm, is required for the former. The wrist can by this means be kept in a position of slight hyperextension without interfering with the movements of the thumb and fingers.

The **Median Nerve** may be damaged in fractures and dislocations of the humerus, but in civilian practice is most frequently injured

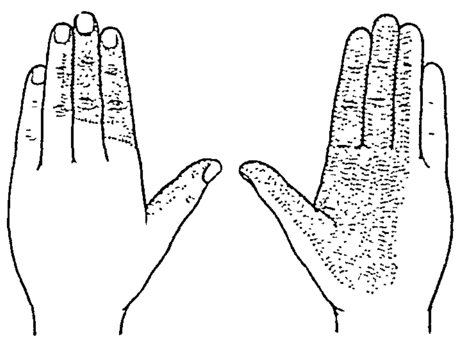


FIG. 180.—DIVISION OF MEDIAN NERVE ABOVE THE WRIST.
The shaded parts indicate the area over which epicritic sensation is lost.

just above the wrist by glass wounds, due either to bursting of bottles, etc., or to thrusting the hand and arm through a window. Gunshot wounds of the *forearm*, above or below the elbow, are frequently associated with it, and compound fractures of the humerus, radius, or ulna may accompany this lesion.

Paralysis, more or less complete, results from these injuries, and is not unfrequently associated with severe causalgia referred to the palmar surface of the hand. The symptoms are tolerably characteristic.

If divided just above the wrist:

A. Anæsthesia. Loss of epicritic sensation over the palmar aspect of the radial side of the hand, as well as of the thumb, index, middle, and half the ring fingers, and over varying portions of the dorsum of the same (Fig. 180); loss of protopathic sensation, including analgesia to pin-pricks over a much more limited portion, varying considerably in different cases with the area of distribution of the terminal branches of the external cutaneous and ulnar nerves (Fig. 16, p. 387).

B. (i.) Paralysis of the outer group of the short muscles of the thumb (*i.e.* abductor, opponens, and outer half of the flexor brevis pollicis), so that the thenar eminence wastese and the movement of ' opposition ' is impaired, the thumb remaining extended by the side of the fingers (Duchenne's ' ape-hand ').

(ii.) Paralysis of the outer two lumbrical muscles, causing loss of power of flexion at the metacarpo-phalangeal joints of the index and middle fingers.

(iii.) Occasionally there is some irregularity in the nerve-supply of the interossei, the abductor indicis in particular not unfrequently receiving nerve impulses from the median; paralysis of this muscle is therefore sometimes present in lesions of the median nerve.

The great impairment of mobility in the hand and fingers so often seen in these patients depends not so much on paralysis of muscles as on the fact that in the majority of cases the tendons at the wrist or the muscle bellies in the forearm are matted together in scar-tissue, or buried in dense adhesions resulting from diffuse septic inflammation. The delay that often precedes such operations also allows adhesions to form in the joints and tendon sheaths of the fingers, which are thereby stiffened; this trouble is of course aggravated when infection is present, the adhesions often becoming so diffuse and dense as to bring to naught the attempt to restore function by a secondary operation (p. 390).

If divided at the bend of the elbow or in the arm, to the above-described symptoms are added:

(i.) Loss of pronation from paralysis of the two pronators.

(ii.) Paralysis of the flexor carpi radialis, causing defective wrist flexion on the radial side and impaired radial abduction.

(iii.) Paralysis of the flexor longus pollicis, of the flexor sublimis, and the outer half of the flexor profundus digitorum, leading to loss of power in the hand-grasp, especially on the radial side, and perhaps hyper-extension of the wrist.

(iv.) Paralysis of the palmaris longus.

Operative treatment on the median nerve is carried out in accordance with the general rules indicated elsewhere, and not unfrequently the nerve is simply bound down in a dense scar-tissue, and merely requires to be freed from this and protected by a pad of fat or buried in muscle. In cases where it has been divided, the scar-tissue must be removed and the ends sutured. This is rendered possible in cases where there is much loss of substance by flexing the wrist and bending the elbow.

The prognosis of operations on the median nerve is not very satisfactory. In successful cases the median flexor group in the forearm may be expected to recover in from six to eight months, whilst the intrinsic muscles of the hand do not show evidence of recovery until after the expiration of twelve months.

The **Ulnar Nerve** is exposed to injury at the wrist, as also in the hollow between the olecranon and the inner condyle of the humerus, and paralysis may be caused by penetrating or gunshot wounds, fractures, blows, implication in callus, etc. Undue exposure of the nerve just above the elbow, either as an anatomical abnormality or as a result of cubitus valgus, renders it liable to injury and to mild attacks of neuritis, and may require to be treated by its transplantation to the front of the condyle.

The symptoms of division of the nerve are very characteristic.

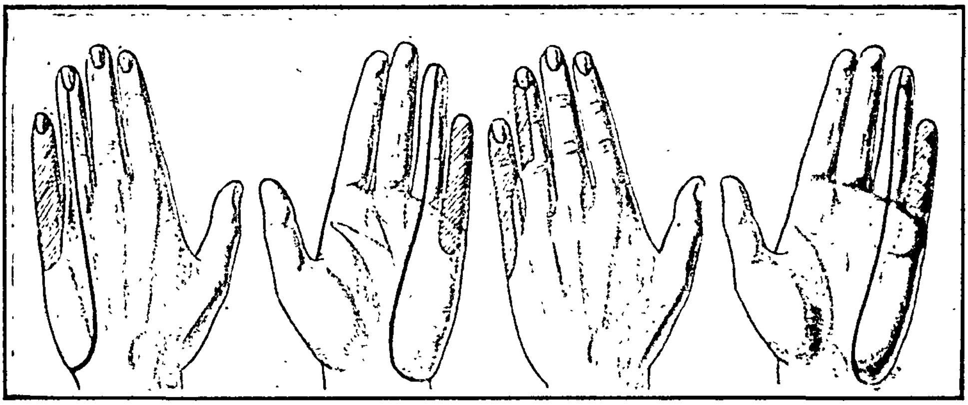


FIG. 181. FIG. 182.

ANÆSTHESIA RESULTING FROM DIVISION OF ULNAR NERVE.

In Fig. 181 the nerve was divided above the origin of the dorsal branch; in Fig. 182 below that branch close to the wrist. The continuous dark line indicates the limits of the loss of epicritic sensation; the shaded area shows the loss of protopathic sensation.

If divided at the elbow :

A. Analgesia or loss of protopathic sensation of the little finger and ulnar border of the palm, back and front, seldom of the ring finger; anæsthesia to light touch (loss of epicritic sensation) of the ulnar side of the front of the wrist and palm, of the back of the hand, and of the little and half the ring fingers, back and front (Figs. 181 and 182).

B. (i.) Paralysis of the flexor carpi ulnaris, causing weakness in flexion and in ulnar adduction of the wrist.

(ii.) Paralysis of the inner half of the flexor profundus, with weakened hand-grasp, especially in the ring and little fingers.

(iii.) Paralysis of the two inner lumbricales and of all the interossei; hence, loss of adduction and abduction of the fingers, with flexion of the two last phalanges in each finger and hyper-extension at the metacarpo-phalangeal joint (*main-en-griffe*) or claw-hand (Fig. 183). The interosseous spaces also become very evident from atrophy of these muscles.

(iv.) Paralysis of the short muscles of the little finger, of the inner group of short thumb muscles (adductor transversus, adductor obliquus, and deep portion of flexor brevis), and of the palmaris brevis.

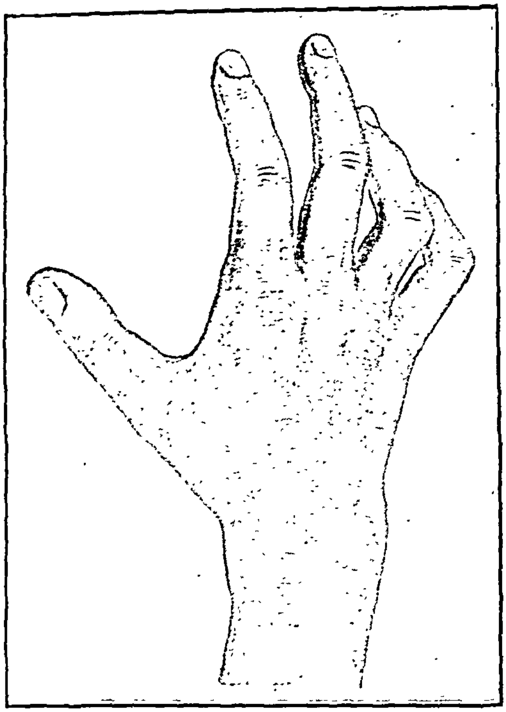


Fig. 183.—Claw-Hand (Main-en-Griffe) from Ulnar Paralysis.

If *divided just above the wrist*, the anæsthesia involves only the palmar aspect of the hand and back of the terminal phalanges (Fig. 181), whilst the paralysis affects merely the short palmar muscles. Additional impairment of movement may, however, arise from septic inflammation of the long tendons and their sheaths.

Treatment.—The nerve, when divided, must be dealt with (according to the rules already given) at the injured spot. It is often difficult to bridge the gap between the two ends, but this is assisted by *bending* the wrist to a right angle. When dealing with the nerve in the neighbourhood of the elbow, flexion of this joint increases the tension on the nerve, owing to its situation behind the internal condyle. It is then desirable to displace the nerve from this position, and bring it into the forearm in front of the condyle, burying it in the muscles.

The prognosis of ulnar nerve operations is as unfavourable as those of the median, and for a similar reason. In both cases tendon transplantation is of little value, since the tendons are frequently embedded in dense scar-tissue.

When both the median and ulnar nerves are divided the sensory loss is shown in Fig. 184.

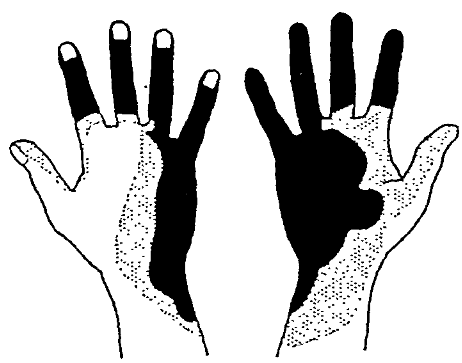


Fig. 184.—Sensory Loss in a Combined Median-Ulnar Nerve Lesion.

The **Intercostal Nerves** are frequently the seat of severe neuralgia, either from chronic neuritis, probably of toxic origin, from compression by tumours or inflammatory lesions of the ribs, or from injury or pressure directed to the

nerve-roots as they emerge from the spine, as in spinal caries (girdle-pain). Herpes zoster or shingles is sometimes associated with such pain, and may be followed by some amount of anæsthesia.

The **Twelfth Dorsal Nerve** is not unfrequently the seat of neuralgia of a somewhat severe type, following its distribution to the anterior abdominal wall and buttock, and occasionally leading to a mistaken diagnosis of some abdominal lesion, *e.g.* appendicitis or chronic ovaritis, and not a few operations have been unnecessarily undertaken in consequence. In some cases it is caused by the undue projection of the tip of the last rib, which becomes injured and inflamed, the nerve becoming adherent thereto; removal of the rib or its tip suffices to cure the patient. In not a few cases of operations on the kidney the nerve becomes entangled in the scar, and this is a source of most troublesome pain, the only cure of which is to cut down, free the nerve, and pull out its central end.

The **Great Sciatic Nerve** is frequently involved in injuries resulting in temporary or permanent paralysis as the outcome of penetrating or gunshot wounds; in ordinary civilian surgery it is an uncommon accident. The injury is usually situated below the gluteal fold, and inasmuch as the hamstring muscles receive their branches above this level, the resulting paralysis is usually similar in type to that caused by a lesion of the external or internal popliteal nerves (more frequently of the former), or of both. If, however, the nerve is damaged near its exit from the pelvis, the hamstring muscles participate in the paralysis. If only a small section of the nerve is damaged in a gunshot wound, severe pain (causalgia) may be experienced in the sole of the foot, and is a distressing and intractable condition during the period of waiting until operation is undertaken. The muscles of the limb must be kept in as good condition as possible by massage and electricity, and deformity of the foot prevented by wearing a suitable support to prevent foot-drop.

Operation.—The nerve is exposed in the back of the thigh by a suitable incision, which in the upper part of the thigh should pass to the outer side of the biceps muscle so as to avoid muscular branches. In the lower part of the thigh it may pass to the inner side of this muscle. If the nerve has been injured not far from the pelvis, it is perhaps better to divide the gluteus maximus close to its attachment to the great trochanter and lift that muscle upwards rather than to divide the muscular fibres in the line of the nerve. A suitably curved incision will be required for this purpose. When the nerve is laid bare, it is freed from scar-tissue so as to expose the nerve-fibres. The surgeon need be in no great fear of being unable to bridge the gap if the knee is fully flexed. Every effort must be made to suture the ends of the nerve accurately, so that the external and internal popliteal segments may be correctly apposed. The knee is kept flexed for about ten days, and then may be gently and gradually extended. The after-treatment is prolonged, and if the patient has regained power in the course of nine to twelve months, he has done well.

In cases where the paralysis persists in spite of operation on the nerve, improvement in the gait may be secured by the use of a suit-

able hinged knee-splint, and by arthrodesis of the ankle or tendon fixation. Under no circumstances should amputation through the thigh be undertaken, except possibly for persisting pain; in a few cases where the foot is badly nourished and ulcerated, a Syme's amputation is admissible and gives good results.

Sciatica, or neuralgia of the great sciatic nerve, is a most painful affection, and often exceedingly intractable. It may arise from the following **Causes:** (*a*) Inflammation of the neurilemma (acute or chronic fibrositis), the result of cold, injury, gout, rheumatism, syphilis, and many toxic agents; (*b*) pressure upon the extrapelvic portion of the nerve, as by aneurisms, tumours, or old-standing dislocations of the head of the femur on the dorsum ilii; (*c*) similar pressure upon the nerve in the pelvis, or as it emerges through the sacrosciatic notch, as from sarcoma or osteoma of the pelvic bones, rectal or uterine cancer, a pregnant uterus, or uterine fibroids; (*d*) pressure upon the nerve-roots in the spinal canal, as from caries or sarcoma or prolapse of an intervertebral disc; (*e*) chronic diseases of the spinal cord, such as tabes (Fig. 185).

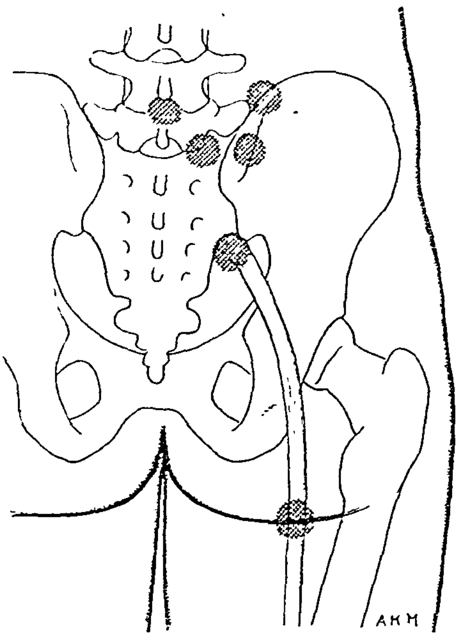


FIG. 185.—THE VARIOUS SITES WHERE THE LESION MAY BE FOUND IN CASES OF SCIATICA.

The **Symptoms** are very characteristic, the pain shooting down the back of the thigh, and being often referred to the toes. It is of a paroxysmal nature, and may be brought on by pressure over almost any part of the nerve or by movements of the thigh, and hence the patient's gait is stiff and shambling. Tenderness in the line of the nerve is felt when the cause is a peripheral neuritis, and the trunk may sometimes be detected on palpation as a thickened cord. The limb is usually kept slightly bent, but complete flexion of the thigh on the pelvis is an impossibility; and if, when the patient is standing against a wall, the limb can be raised to a right angle with the knee extended, it is certain that sciatica is not present. Inspection of the buttocks in a case of genuine sciatic neuritis reveals a loss of the gluteal fold and marked flattening of the nates on the affected side, causing noticeable asymmetry. Careful examination of the patient's pelvis must always be made before determining that a case is 'merely sciatica.'

The **Treatment** necessarily varies with the cause. If due to neuritis or perineuritis, general anti-syphilitic or anti-rheumatic measures may be adopted, and blisters or sedative remedies in the more acute cases applied to the back of the thigh. Hypodermic injections of morphia

may be required at night, and the nerve itself may be injected with saline solution. Injections into the nerve of 1 c.c. of the following solution once or twice a week for three weeks will often do substantial good: phenazonum, ʒii.; cocain. hydrochlor., gr. ii.; aqua destillata, ʒii.ss. Failing such measures, *stretching of the nerve* may be employed, and not unfrequently excellent results follow. It may be accomplished without operation by flexing the thigh upon the abdomen and then extending the knee; in cases of sciatica an anæsthetic will by required for this, but it may be attempted before undertaking operative procedures.

The nerve is best *exposed* for stretching at the point where it emerged from under cover of the gluteus maximus, midway between the tuber ischii and the great trochanter. The patient lies in the prone position with the limb slightly flexed, and a 4- or 5-inch incision is made vertically downwards from the gluteal fold in the middle line of the thigh. The lower border of the gluteus maximus is first exposed, and its fibres are seen running downwards and outwards. The hamstring muscles emerging from under it are drawn inwards, and the nerve is found ensheathed in loose connective tissue; it is stretched, by a finger hooked under it, both peripherally and proximally, using a considerable degree of force, which must be applied steadily and continuously, not in jerks. The effect is to cause some loss of conductivity for a time by breaking up the medullary substance; external adhesions are snapped, and a beneficial hyperæmia is induced, whereby toxic material is eliminated.

The **External Popliteal Nerve** may be divided during a subcutaneous tenotomy of the biceps, to which it lies immediately internal; or compressed, as it winds round the neck of the fibula, by strapping, bandages, or splints; or it may be injured in fractures of the neck of the fibula. It is frequently injured in gunshot wounds—three times as often as the internal popliteal nerve. Total division causes anæsthesia of the dorsum of the foot and of a varying portion of the front and outer side of the leg, together with paralysis of the extensor and peroneal groups of muscles. In the earlier stages, inability to dorsiflex the foot results in a condition of 'drop-foot,' but later on the contraction of the unbalanced opposing groups results in the paralytic form of talipes equino-varus. The nerve may be exposed by making an incision 1½ inches long to the inner side of the biceps tendon, terminating at the neck of the fibula, or just below the neck of that bone. See also on Treatment of Paralytic Talipes Equinus (Chapter XIX.).

The **Internal Popliteal Nerve** is much less exposed to injury owing to its more sheltered position. Division results in loss of epicritic and protopathic sensation over the sole of the foot, and of epicritic sensation for the plantar surface of all the toes and for the dorsal aspect of the outer four; also in paralysis of the calf muscles, flexors of the foot and toes, and of the short muscles of the sole. Paralytic talipes calcaneo-valgus is very likely to ensue. The nerve is laid bare by a vertical incision in the middle of the popliteal space which should avoid the short saphena vein. After division of the deep fascia, the nerve is the most superficial structure.

If the **Tibial Nerves** are divided, the resulting effects are more limited; thus, paralysis of the extensors of the foot and paralytic talipes equinus result from division of the anterior tibial; and paralysis of the short and long flexors of the foot and of the interossei, with resulting talipes cancaneo-valgus, follow lesions of the posterior tibial. The nerves may be exposed in the same way as the accompanying arteries (p. 353).

The **Sympathetic Nerve-trunk** in the neck is occasionally compressed by aneurisms or tumours. If merely irritated, dilatation of the pupil on the same side and unilateral sweating of the head and face are produced; but, if divided, the pupil is contracted from unbalanced action of the third nerve. The inferior cervical ganglion, together with the first and second dorsal ganglia, are removed in cases of Raynaud's disease, and the results are satisfactory. (See Chapter XVI.)

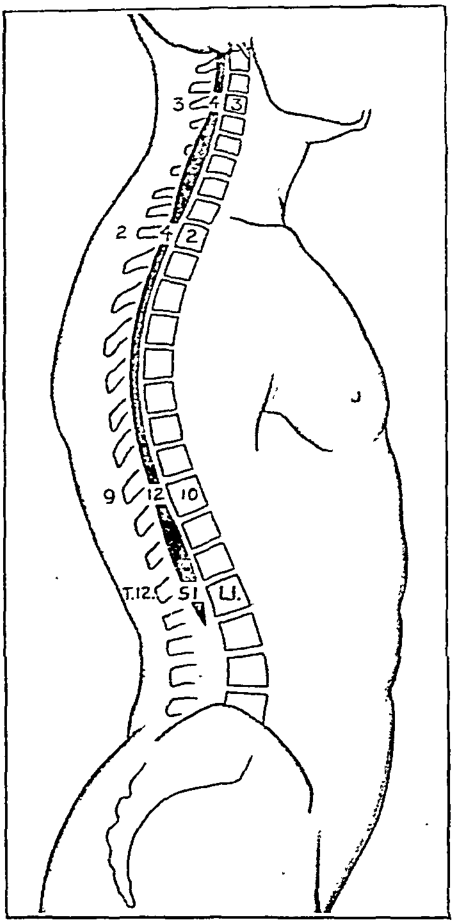


FIG. 186.—RELATION OF SPINAL CORD TO SPINAL COLUMN.

The Nerve-Roots.

It is a well-known fact that during the development of the embryo the primitive spinal cord, which was originally co-terminous with the trunk and with the vertebral column, gradually lags behind in its growth, so that at birth and subsequently it does not extend down the canal further than the lower border of the first lumbar vertebra. This necessarily involves a displacement of the attachment of the spinal nerves upwards, so that these points of origin of the nerves do not correspond to the intervertebral foramina, and a variable length of the nerve exists within the canal formed at first by the junction of the anterior or motor ramus with the ganglionated posterior or sensory ramus. In the cervical region each spinal segment is about one vertebra above its corresponding body; in the upper dorsal region this interval amounts nearly to two vertebræ; whilst all the spinal segments corresponding to the lumbar, sacral, and coccygeal nerves are crowded between the tenth dorsal and the first lumbar vertebræ (Fig. 186).

The nerve-roots after this downward intraspinal course pass through

the intervertebral foramina, where they are exposed to injury and pressure, and after various divisions and combinations constitute the peripheral nerves. It must be remembered that almost all the peri-

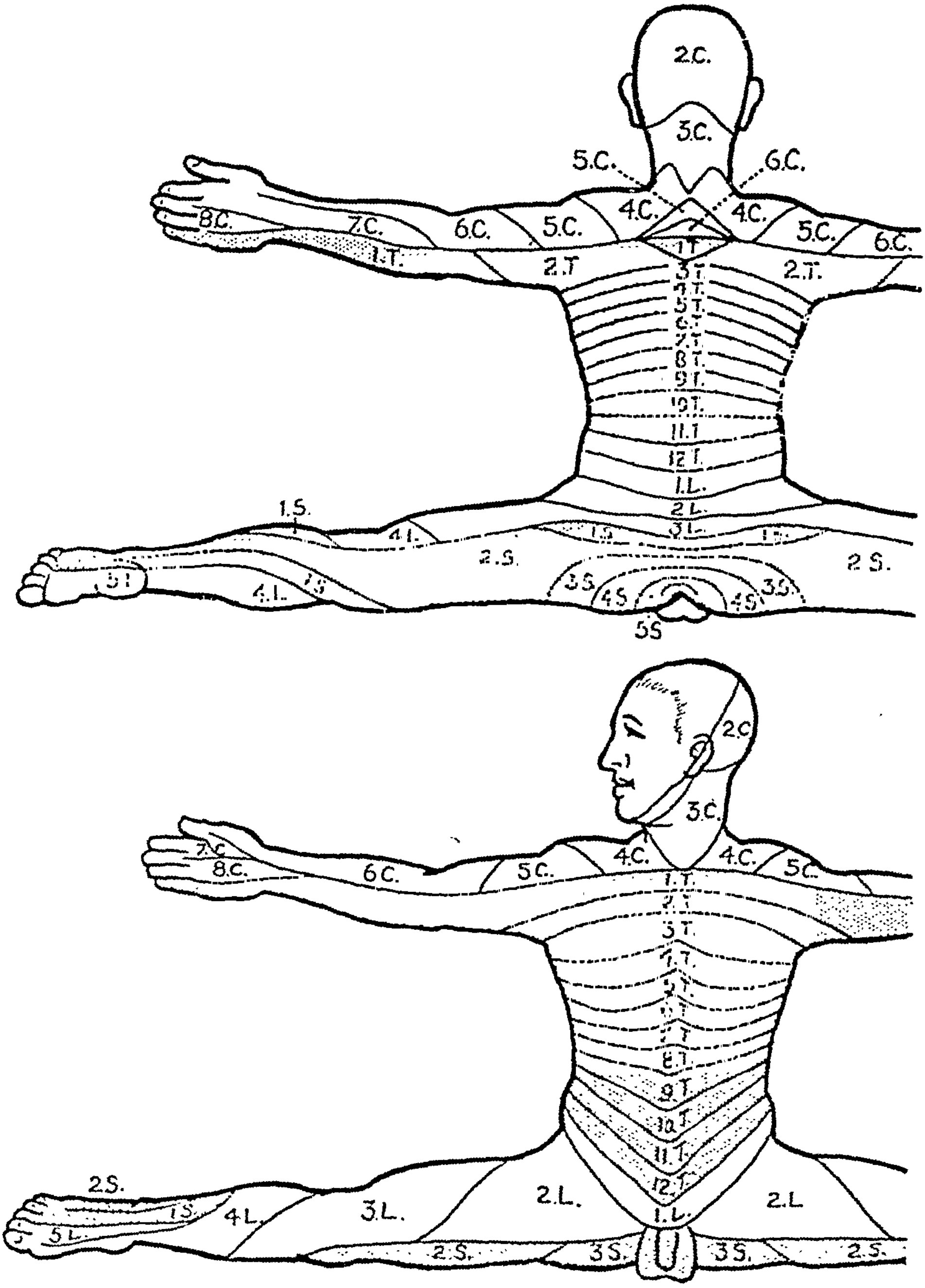


FIG. 187.—NERVE-ROOT AREAS: ANTERIOR AND POSTERIOR ASPECTS OF TRUNK.

pheral nerve-trunks are derived from a number of nerve-roots, and the complex distribution of these has been carefully worked out. It follows that the distribution of sensation over the trunk according to the nerve-roots is a very different thing to that of the peripheral

nerves, and the practitioner and student must carefully study the diagrams appended (Fig. 187) in order to familiarize themselves with this arrangement. Particularly noticeable is the amount of overlapping of sensory areas, a provision whereby defective sensation due to localized injuries may be minimized. Sherrington has shown that in apes cutaneous anæsthesia will not result from the division of any two consecutive posterior nerve-roots, but only when three are divided; this has been confirmed in man. The control of muscles or groups of muscles is similarly distributed over two or three consecutive nerve-roots, presumably with a similar object; whilst the nerve-fibres from

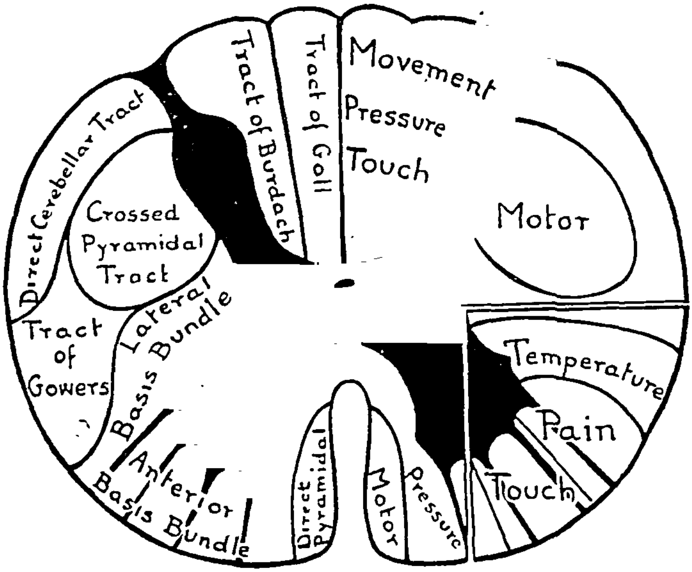


FIG. 188.—DIAGRAM SHOWING AREA OF SPINAL CORD WHICH IS INCISED IN THE OPERATION OF CHORDOTOMY.

muscles, tendons, ligaments, etc., upon which the muscular tone and control of the limbs so much depends, also enter the cord by several nerve-roots.

Pressure on the nerve-roots may be caused by tumours of the spine or spinal cord, by tuberculous or gummatous lesions, or by callus or adhesions forming about the intervertebral foramina. Intense neuralgia is the most prominent symptom, together with hyperæsthesia; this, it will be noted, always follows the nerve-root areas, and not those of the peripheral nerves. Herpes zoster may be induced by the affection, and in time anæsthesia may follow.

Similar symptoms may arise from slight displacements of the vertebræ and partial fractures; but even these are usually of a complicated nature, and involve considerable ligamentous lesions; they can only be diagnosed with certainty by the most careful radiography, and may give rise to nerve-root symptoms. The peripheral phenomena are governed by the anatomical distribution of the nerves, and certain well-defined and localized manifestations, mainly of the neuralgic or paretic type, correspond to each nerve-root involved. This statement is no justification for the claim that visceral diseases

generally are due to slightly unrecognized displacements of the spine, which can be cured years later by manipulation of the affected vertebra, and that usually without any anæsthetic.

Chordotomy has now completely replaced Förster's operation, or division of the posterior roots. The operation is performed for the relief of intractable pain, and consists of:

(1) Section of the antero-lateral tracts; or
(2) Median chordotomy

Chordotomy is indicated for the following conditions:

(i.) Intractable neuralgia, due either to irremovable pressure or to an ascending neuritis, usually as a result of malignant disease.
(ii.) For severe cases of gastric crises and the lightning pains of tabes dorsalis.
(iii.) In certain cases of painful osteo-arthritis of the hip.

1. **Section of the Antero-Lateral Tracts.**—An ordinary laminectomy operation is performed; the actual site of section is taken well above the part of the cord where the affected sensory nerves reach the cord. The fourth and fifth thoracic segments are usually chosen. After exposure of the cord it is rotated by traction on a ligamentum denticulatum, the dural attachment of which has been divided. In this way the lateral aspect of the cord is exposed. The guarded blade of a fine knife is now introduced into the cord at a point immediately anterior to the attachment of the ligamentum denticulatum. The blade is passed transversely to a depth of 3 mm. into the cord, and is then brought out by cutting through the cord in a forward direction. The knife leaves the cord about 1 mm. from the mid-line (Fig. 188). The antero-lateral column divided is, of course, on the opposite side to that from which the painful stimuli are arising (Fig. 189).

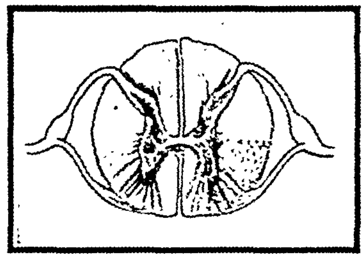


FIG. 189.—DIAGRAM SHOWING THE AMOUNT OF TISSUE DIVIDED IN LATERAL CHORDOTOMY.

2. **Median Chordotomy.**—In this operation the pain fibres are incised as they cross from one side of the cord to the other. To be successful, accurate knowledge of the situation in which the affected fibres cross is essential. The operation has technical drawbacks, because there is considerable difficulty in keeping to the mid-line while making the incision in the cord, and there is always some risk of damage to the anterior spinal artery.

For these reasons antero-lateral tract section (Spiller's operation) is preferable.

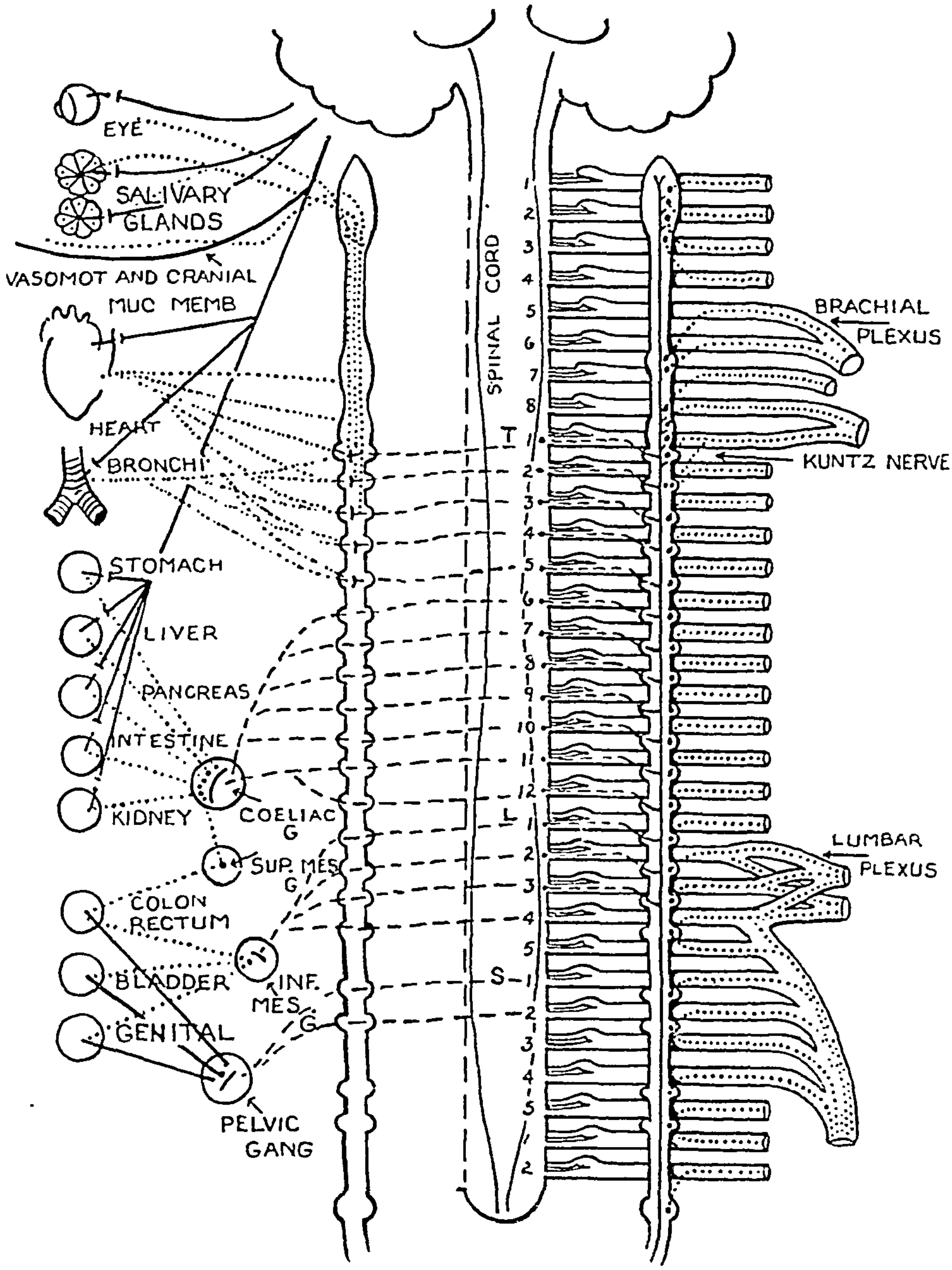
CHAPTER XVI.

THE SURGERY OF THE SYMPATHETIC NERVOUS SYSTEM.

In 1732 Winslow described the ganglia of the sympathetic nervous system, while at the beginning of the nineteenth century Bichat put forward the idea that there were two separate and independent nervous systems in the body. The physiological experiments of Langley and Gaskell indicated the function of these nerve cells and fibres and the course the individual impulses took. This paved the way for surgical operations and the present-day attitude to the surgery of this subject. The earlier operations were rather unfortunately selected in the hope that diseases difficult of treatment, such as epilepsy and angina pectoris, might be benefited. However, credit is due to these earlier operators, as they were the first to establish a new surgical principle, namely, that of attacking the nerve-supply to a dysfunctioning organ rather than the organ itself.

In 1916 Leriche began his work on periarterial neurectomy for vascular disease of the extremities, and with his work a new interest in the subject was aroused. The steps which have led to present-day conceptions have been romantic, as the modern conceptions have arisen as clinical observations made after operations which were in themselves failures. Thus, in 1923 Hunter and Royle, working together on the principle that sympathetic fibres to voluntary muscles controlled the tone of these muscles, commenced ramisectomy for spastic paralysis. These operations were unsuccessful, though initial claims of success were made. Observers, however, noted that while the paralyzed limbs did not become any less spastic, they did become much warmer, and that nutrition in the limb was improved, as evidenced by the healing of pressure sores, etc. This led to the modern operations for certain peripheral arterial diseases. Again, many of these patients were very constipated, and it was noticed that after the operation their bowels were readily moved. This led to the operation now performed for megacolon.

Anatomy.—A detailed anatomical account will not be given here, only a summary sufficiently full to enable the various surgical procedures to be followed. The nomenclature is somewhat variable, and among the terms used are: the Sympathetic Nervous System, the Vegetative Nervous System, the Autonomic Nervous System. These titles are freely used as synonyms. The best term for the whole system is the **Autonomic Nervous System,** which is divided into two portions, the cranial and sacral outflow, termed the 'parasympathetic nervous system,' and the thoracic outflow, or sympathetic nervous system. These two systems balance and antagonize each other. As



THE AUTONOMIC NERVOUS SYSTEM IN DIAGRAMMATIC REPRESENTATION.

- - - - - - - - - - - - - - - - - - -	=	Preganglionic fibres.
....	=	Post-ganglionic fibres.
――――――――――――――――	=	Parasympathetic nerves.

On the right-hand side of the chart the somatic outflow is depicted; the viscera; outflow is shown on the left-hand side.

there is as yet no effective surgery of the parasympathetic system it will not be further considered.

The sympathetic nervous system consists of:

The preganglionic fibres.
The ganglionic trunks.
The visceral ganglia.
The post-ganglionic fibres.

The preganglionic fibres or white rami communicantes are fibres arising from the cells of the lateral horn of the grey matter of the spinal cord in all the thoracic segments and the upper three lumbar segments. These fibres leave by the anterior spinal roots and pass to the ganglionated trunks. They may arborize in the nearest ganglion or pass up and down the ganglionated cord to higher or lower ganglia, or they may pass through the ganglionated cord to end in a visceral ganglion. A few run direct to the medulla of the suprarenal gland.

The ganglionated trunks extend from the under aspect of the skull to the coccyx as a paired chain of ganglia and fibres. There are three cervical ganglia, eleven or twelve thoracic, four lumbar, and four sacral. The cords join over the coccyx to form the ganglion impar (see Plate VII.).

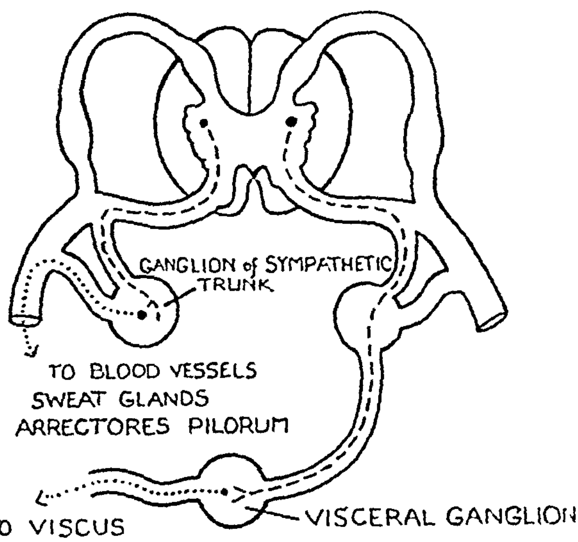


FIG. 190.—TRANSVERSE SECTION OF THE SPINAL CORD, SHOWING THE SYMPATHETIC OUTFLOW.

The visceral ganglia contain the cells whose axons pass direct to the abdominal viscera. Their preganglionic fibres pass through the ganglionated trunks, but they do not synapse there. The main visceral ganglia are the cœliac and the superior and inferior mesenteric ganglia.

Post-ganglionic fibres or grey rami communicantes run from the cells of the ganglionated trunk via the spinal nerves to their ultimate distribution in blood-vessels, sweat glands, etc. These grey fibres form a definite bundle, and they enter every somatic nerve-root (Fig. 190).

Certain ganglia and nerves require special description because of their surgical importance. They are:

The stellate ganglion.
Kuntz's nerve.
The lumbar ganglia.
The presacral nerve.
The pelvic nerve of the parasympathetic.

The Stellate Ganglion.—The sympathetic nerve-supply to the upper extremity comes from the inferior cervical and the first and second thoracic ganglia. The inferior cervical and the first thoracic ganglia are frequently fused into one mass, the stellate ganglion. To denervate the upper limb it is important to remove more than the stellate ganglion, as the second thoracic ganglion frequently sends a contribution termed 'Kuntz's nerve,' which either runs direct to the first thoracic spinal nerve or to the first thoracic nerve via a branch from the second thoracic nerve. The stellate ganglion lies anterior to the spinal nerves in a groove on the neck of the first rib.

The Lumbar Ganglia.—These ganglia, four pairs in number, are somewhat irregularly disposed. The right chain lies behind and slightly lateral to the inferior vena cava, while the left chain lies lateral to the aorta. The first ganglion lies just above the renal pedicle. The other ganglia are irregularly disposed below it. The ganglia give off branches to the pre-aortic plexus, a very irregular network of fibres anterior to the aorta. From this plexus arises a collection of fibres of great surgical importance—the presacral nerve. This nerve, more accurately termed prelumbar, consists of those sympathetic fibres which lie in front of the fourth and fifth lumbar vertebræ. It lies at the bifurcation of the aorta between the common iliac vessels. It is about 2½ inches in length, and it is the nerve of supply to the pelvic viscera. Lying close to the presacral nerve on its left side is the pelvic splanchnic nerve, the parasympathetic portion of the nervi erigentes, and the motor nerve to the colon. This fact is of importance, as in dividing the presacral nerve it is important not to damage the pelvic splanchnic nerve. This nerve runs up to the inferior mesenteric artery near, but not at its origin from the aorta. It is distributed with that artery to the colon.

Indications for Operations on the Sympathetic Nervous System.

At the present time full agreement has not been reached as to the conditions likely to benefit by sympathectomy. Sympathetic denervation has been widely tried for a diversity of conditions, and many disappointments have been encountered which could readily have been predicted. It must be appreciated that the only operation known is a denervation, and the problem resolves itself into finding suitable diseases, suitable individual cases, and finally the correct amount of denervation to perform. Certain disease groups emerge with definiteness, while some remain in the experimental state. They may be enumerated as follows:

Diseases of the Vascular System :

I. *The Peripheral Vessels :*
- Raynaud's disease.
- Buerger's disease.
- Acrocyanosis.
- Erythromelalgia.

II. *The Central Vessels :*
- Angina pectoris.

Diseases of the Abdominal Viscera :

Hirschsprung's disease.
Spastic constipation.
Cardiospasm.
Renal sympathetico-tonus.
Cord bladder.

Sympathectomy for Pain :

Dysmenorrhœa.
Tuberculous cystitis.
Carcinoma of the bladder.
Causalgia.
Trigeminal neuralgia.
Painful ulcers.
Pain of gangrene.

Symptomatic Group :

Scleroderma.
Chronic arthritis.
Retinitis pigmentosa.
Anterior poliomyelitis.
Hyperidrosis.

This list is in no sense exhaustive, and it deliberately omits many suggested indications which are highly experimental.

These disease groups can now be considered individually with their investigations to determine suitability for operation.

I. **Diseases of the Vascular System.**—There is a group of related diseases of the peripheral vessels which is characterized by the fact that the symptoms of ischæmia and pain appear before any pathological changes are detectable in nerves or vessels. It is also characteristic that these diseases are progressive, and that later gangrene will occur. These diseases may be termed vaso-spastic in their origin, the spasm later leading to an obliterative change in the vessels. If these cases are seen in the preliminary period of spasm they are essentially amenable to sympathectomy, and much improvement amounting to an immediate cure may be expected. If organic changes have supervened, however, the case is unlikely to benefit. The surgical problem after the preliminary examination and diagnosis resolves itself into an estimation of the degree of sympathetic activity. Chief of these diseases is Raynaud's disease.

Raynaud's Disease.—This is a disease of the extremities; the fingers, feet, ears, and nose may all be affected, but the hands and fingers are more frequently and more severely attacked than the other parts. The disease is much more common in women than in men, and characteristically occurs as a series of attacks. These attacks are usually in response to cold, but they may be precipitated by emotion. In an attack the hands become cold and numb, due to contraction of the digital vessels. Fine movements become impossible, and the fingers ache. The colour may be pale or cyanosed, depending on the capillary state. The attack is followed by a stage when the fingers become red

and tingling, and very painful. If the hand be suddenly warmed by placing it in hot water the skin turns a deep violet colour, and it is intensely painful. After numerous attacks organic changes set in in the vessels and gangrene ensues. True gangrene is preceded by chronic ulcers, bone rarefaction, and stiffening and induration of the skin. Raynaud's disease has to be differentiated from syringomyelia and the effects of a cervical rib (see Chapter XIX.). Allied conditions are acrocyanosis and pneumatic drill disease.

Investigations.—Raynaud's disease, if seen at an early stage, is eminently suited to treatment by sympathectomy. It is obvious, however, that the cases must be investigated to show that there is no marked organic change in the vessels. Measures are taken temporarily to paralyze the sympathetic supply to the extremity. If the temperature of the extremity rises markedly, then a large element of spasm is presumed present and sympathectomy is indicated. These measures will now be considered in detail.

Methods of Investigation in the Upper Limb :

(*a*) The hot-air bath.
(*b*) The fever test.
(*c*) Local or regional anæsthesia.

(*a*) *The Hot-Air Bath.*—The patient is placed in the hot-air chamber and readings are taken of the temperature of the limb under investigation (several digits), the mouth and the chamber itself. The warm air is then turned on. The rise in temperature in the limb and mouth are both recorded. This may be represented as $\frac{\text{skin rise} - \text{mouth rise}}{\text{mouth rise}}$. This index is termed Brown's vasomotor index. It should be more than 1·5 before sympathectomy is worth while.

(*b*) *The same test* can be carried out by promoting fever by an intravenous injection of T.A.B. vaccine. A moderately severe degree of fever must be produced.

(*c*) *Local Anæsthesia.*—If it is possible to block the sympathetic nerves to the limb by novocaine injection, then the effect of a transitory sympathectomy can be observed. In the arm this may be done by injecting the ulnar nerve at the bend of the elbow and observing the temperature change in the little finger; the branchial plexus may be injected, or, better, a paravertebral series of injections made and the whole arm observed.

Treatment.—Any case of Raynaud's disease which on investigation shows a large element of spasm should be strongly advised to submit to sympathectomy. It is probable that even in less favourable cases the operation will be performed in the hope of securing amelioration, and perhaps healing of the trophic sores. In an advanced case sympathectomy is almost useless. The final permanence of the so-called 'cures' by sympathectomy is as yet unknown. There is little doubt that many cases relapse to some extent, though not usually to the full pre-operative incapacity. The relief of pain is usually the most striking phenomenon, although attacks of cyanosis and mottling may still go on.

The operation to be performed for the upper limb is stellate

ganglionectomy with removal of the second thoracic ganglion (to include Kuntz's nerve). This operation is usually called 'cervico-thoracic sympathectomy.' Its technique will be described at the end of the chapter. It must be remembered that Raynaud's disease can also affect the lower extremities, and here lumbar sympathectomy must be performed. The results of sympathectomy for Raynaud's disease are better in the lower limb than the upper limb. This is probably not due to any inherent difference, but to the fact that there is greater sympathetic control of the lower limbs. Raynaud's disease seldom, if ever, affects the lower limbs apart from the upper limbs, and in these cases a quadruple sympathectomy may be indicated.

Buerger's Disease (*syn.:* Thrombo-angeitis Obliterans).—This is a disease mainly affecting men (95 per cent.) in the fourth decade of life. It affects the lower limbs almost exclusively, and is almost invariably bilateral. It is slowly progressive, and in 25 per cent. of cases bilateral amputation above the knee will be the ultimate result. There is a definite higher racial incidence among Jews, but the disease is by no means confined to them. Attacks of superficial phlebitis of veins are concurrent with the occlusive thrombosis of the arteries. It is a striking fact that the largest vessels, *i.e.* the common femoral, escape, while below this level the vessels in a late case are extensively involved in the obliterative process. One of the earlier symptoms is 'intermittent claudication,' severe cramping pain in the back of the legs following exercise and relieved by rest and brought on again by further exercise. The cause of this condition is unknown. Buerger, who first fully described it, thought it had a toxi-infective basis, and pointed out that most of the cases were excessive cigarette smokers. Many observers believe that there is a preliminary period of sympathetic overactivity as evidenced by arterial spasm, and that these cases can be benefited by operation. That there is an element of spasm in these cases is undoubted, and it should always be searched for, but it is unfortunate that by the time these cases have come for treatment much vascular occlusion is usually present. Buerger's disease can be differentiated from Raynaud's disease by the sex incidence, the extremity affected, and the presence of superficial phlebitis. Deep thrombosis of main arteries is indicated by the disappearance of the peripheral pulses. This is unknown in Raynaud's disease.

Special Investigations in Thrombo-angeitis Obliterans.—The sympathetic control to the lower extremities can readily be removed by anæsthetizing the body to the level of the umbilicus by a spinal anæsthetic. The temperature rise of the limb can then be measured. A big rise in the temperature indicates a high degree of spasm, and much benefit, even if temporary, can be expected from sympathectomy. The use of a spinal anæsthetic is almost routine in the investigation of the legs, and under the same anæsthetic, if the report is favourable, the sympathectomy may be performed. If a spinal anæsthetic is not indicated, a paravertebral block of the sympathetic may be tried instead.

In Buerger's disease a considerable degree of occlusion may be expected, and this can be investigated by arteriography, *i.e.* radio-

grams taken after the injection of thorotrast into the femoral artery. There is evidence to suggest that such thrombosed portions of the arteries are as much the cause of the pain felt as any resultant ischæmia, and there is also reason to believe that these areas act as foci of irritation and are liable to cause a spread of the disease.

Treatment.—If the investigations point to the presence of vasospasm, then a lumbar sympathectomy should be performed. The technique of this operation will be described at the end of the chapter. Some authorities advise a bilateral operation even in an early case where the symptoms are unilateral. They argue with some force that the second limb is usually involved at a later date, and that sympathectomy at this stage might prevent the onset. It is true to say that ill-effects as a result of sympathetic denervation have never been observed, although the beneficial effects anticipated have not always eventuated. This observation is true of all sympathetic operations in all the regions of the body. The only possible exception is the minor inconvenience of a Horner's syndrome.

The results of lumbar sympathectomy for Buerger's disease are still under consideration. Relapses after a two to three year period of improvement are not unfrequent. This, however, should not preclude operation, as the period of relief and improvement means much to the patient. It merely should act as a brake to a too optimistic prognosis. Buerger's disease contrasts with Raynaud's disease in that in the former organic changes in the vessels appear at a much earlier date, and hence the amount of benefit is not likely to be so great. During an active stage of the disease, *i.e.* when phlebitis or deep thromboses are present, the treatment should be medical.

Angina Pectoris.—This disease was one of the earliest to be treated by operations on the sympathetic nervous system. The operations have had two underlying conceptions: one, the abolition of the sensory pathway for cardiac pain, the other the removal of the pathway down which noxious impulses causing an attack might travel. At the present time the rationale is considered as an attack upon the sensory pathway. Many authorities still hold that the pain of angina is of value to the patient, as it is a warning signal of the heart's capacity limit, and the fear of an attack with its dreadful pain is a lively and wholesome deterrent from too much exercise. On the other hand, the pain is so severe that with a patient sufficiently fit and amenable to instruction afterwards, then to relieve the pain of the attacks is only humane. Cervico-thoracic ganglionectomy has proved of benefit in a number of these cases (about 60 per cent.). As an alternative to this rather extensive operation a paravertebral alcohol injection may first be tried. The criterion of a successful injection is the production of a Horner's syndrome. It is usually sufficient to operate or inject on the left side only. While the pain is relieved in a successful case, the patient often on effort experiences peculiar sensations in the præcordial region. These sensations should be taken as a danger warning that the safety limit has been overstepped.

II. **Diseases of the Abdominal Viscera—Hirschsprung's Disease** (*syn.:* Megalo-colon).—In 1886 Hirschsprung defined this condition

as 'a congenital high-grade dilatation of the colon with thickening of all its tunics, especially the tunica muscularis, with retention of large quantities of fæcal matter.' The disease is commonly manifest in childhood, and is rather more common in males. Adult cases have been reported, but 60 per cent. have symptoms before fifteen years of age. Sometimes a similar condition occurs in the urinary tract with hydronephrosis, hydro-ureters, and a large bladder. It is important to remember that in the colon there are numerous sphincters, notably at the recto-sigmoid junction and the middle of the transverse colon. It is these sphincters that account for the not unfrequent limitation of this condition to one portion of the colon only. In 50 per cent. of cases only the sigmoid loop is affected. The distension, however, may be enormous. It is partly fæcal, but mainly gaseous in origin. The distension may cause circulatory and respiratory embarrassment. The leading symptom is constipation. For days or weeks no motion is passed. Aperients are valueless, but enemata give temporary relief. Attacks of subacute obstruction are not unfrequent. Signs of auto-intoxication supervene later, and the child has a sallow cachectic look (Fig. 191).

FIG. 191.—CHILD WITH HIRSCHSPRUNG'S DISEASE, SHOWING ENORMOUS DILATATION OF THE SIGMOID COLON.

The diagnosis is confirmed by radiological examination after a barium enema has been administered. This procedure can also be combined with an investigation as to suitability for operation. An enormous amount of enema (8 pints or more) can often be run into the bowel. Skiagrams are taken and the absence of haustration noted. The child is then rolled on his side and a spinal anæsthetic administered, sensation being abolished to the level of the umbilicus. In a favourable case fairly vigorous peristalsis is induced and some of the enema is returned. Skiagrams will now show haustration and a diminished bowel calibre (Fig. 192). If there is a definite change under the anæsthetic which temporarily paralyzes the sympathetic outflow, then benefit is to be anticipated from a sympathectomy.

There are numerous operations in vogue at the present time; the two most popular are:

(*a*) Removal of the upper part of the presacral nerve and periarterial neurectomy of the inferior mesenteric artery.

(*b*) Bilateral division of the lumbar splanchnic nerves.

Following the operation a period of colonic irrigation and medical treatment may be necessary. The results are as a rule very gratifying, and sometimes highly dramatic. Failures may follow a too timid operation or the selection of a very advanced case where the musculature of the colon has atrophied.

Chronic Constipation.—There are many cases of chronic constipation which prove very resistant to the usual medical measures. These cases are worth investigating as to the likelihood of benefit by sympathectomy. This operation should never be performed without the preliminary barium enema spinal anæsthetic test described above. Operations at random discredit a useful procedure and give very disappointing results. Sympathectomy is undoubtedly of considerable benefit in selected cases of chronic constipation.

FIG. 192.—BARIUM ENEMA IN A CASE OF A CHILD WITH HIRSCHSPRUNG'S DISEASE (SAME CASE AS FIG. 191).
The enormous dilatation of the sigmoid colon is well seen.

Cardiospasm.—This condition has been described under the section of 'Diseases of the Œsophagus' (Chapter XXXII.), and its features need not be detailed here. There is a steady accumulation of evidence to suggest that this disease is a true cardiospasm, *i.e.* due to tonic contraction of the cardiac sphincter the result of over-action of the sympathetic nerves. Much experimental work has been done, and recently human cases have been subjected to sympathetic denervation with encouraging results. The sympathetic supply to the lower œsophagus runs along the left coronary artery. The usual operation of denervation consists in dividing the vessel in such manner as to include the maximum amount of connective tissue, which contains the sympathetic nerve fibres, in the ligature. Of course not every case of cardiospasm should at once be subjected, to operation, the simple methods of dilatation with mercury bougies.

etc., being tried first. In stubborn cases a sympathectomy will frequently be palliative, if not curative. The method should certainly supersede the older short-circuiting anastomoses, which were difficult and hazardous.

Sympathectomy in Urinary Conditions—Renal Sympathetico-Tonus.—This term has been applied to certain types of hydronephrosis without demonstrable organic cause, and to attacks of renal pain due to increased intrapelvic tension. In these cases a pyelogram shows delay in emptying of the pelvis. The pain in these cases comes typically in attacks, is unilateral, and is relieved by eserine. It is obvious that in investigating these cases the greatest care must be taken to exclude any organic affection of the kidney or ureter. These cases are definitely benefited by a sympathectomy. If a hydronephrosis complicates the spasm, then plastic operations upon the renal pelvis may also have to be performed. The operation of renal denervation is performed by delivering the kidney through the loin and exposing the pedicle as far as practicable in a medial direction. The pedicle is then systematically stripped of fat and connective tissue, working from the mid-line towards the kidney. An injection of eserine at this stage should show powerful contractions of the pelvis and ureter.

Hydro-ureter.—Presacral neurectomy has been practised in cases of hydro-ureter. Some successes have been reported.

Cord Bladder.—Spinal cord injuries are especially liable to be followed by the condition termed 'cord bladder.' Immediately following the injury there is retention of urine, followed by 'retention with overflow' if treatment has not been instituted. In a favourable case at a later date an automatic bladder develops. These cases can be potentially benefited by a presacral neurectomy. The sympathetic outflow acts as the inhibitor to the detrusor urinæ muscle and as motor to the vesical sphincter. Sympathetic denervation can, therefore, remove the brake, though it cannot supply additional motor power. If reasonable motor power exists, then it is justifiable to consider a presacral neurectomy.

III. **Sympathectomy in Painful States.**—The existence of a sympathetic afferent pathway has long been suspected, but has been, and still is, difficult to prove. Evidence is, however, steadily accumulating to suggest the presence of afferent fibres. It is certain that many painful conditions are improved by sympathetic denervation operations, though the manner in which benefit is obtained is not always obvious. Thus it is impossible to draw up a definite category of conditions where sympathectomy is performed for pain. In some of the conditions previously noted the relief of pain (*e.g.* in Raynaud's disease, angina pectoris) has been almost as marked as the clinical improvement in other respects. There are, however, certain diseases where sympathectomy may be indicated, not so much as a curative measure, but to relieve the pain. First among such conditions may be mentioned painful pelvic states.

Dysmenorrhœa.—Certain cases of dysmenorrhœa which show no major gynæcological organic lesion, but which are usually associated

with a small uterus and an elongated cervix, are relieved by a presacral neurectomy. These cases generally are hypoplastic as regards ovarian and uterine function. Case selection is difficult, and the usual gynæcological measures should be tried first. If these prove unsatisfactory, a presacral neurectomy frequently procures relief and certainly provides the opportunity for a thorough intra-abdominal investigation of the pelvic viscera.

Inoperable Bladder States.—The later stages of tuberculous cystitis and carcinoma of the prostate or bladder are pitiable in the extreme. Bladder cramps, frequency and strangury deprive the patient of sleep and completely exhaust him. If the case is too advanced for the radical forms of treatment, then a presacral neurectomy may often be beneficial. The operation is at least worth trying. It is, of course, considerably safer than cordotomy.

It is customary to perform a presacral neurectomy in the preliminary stages of the various operations of excision of the rectum in the hope that local recurrence may be relatively painless. The efficacy of such a step is doubtful.

Causalgia.—Causalgia literally means a burning pain, and this is a very apt description of the type of peripheral pain to which the term is usually applied. Causalgia usually affects the extremities after minor injuries or minor amputations of digits. It is most commonly found in the distribution of the median nerve. The condition with its marked hyperæsthesia and intense subjective burning pain becomes manifest as a rule during the healing period, rather than during the active stage of the wound or injury. Trophic changes appear in the part affected. The finger becomes tapered, the skin red and shiny, the nails curved and brittle. The skin is warmer than the rest of the hand. The incapacity is extreme.

This condition in the past has proved extremely resistant to treatment. Nerve injections and nerve sections, and even root sections, have often failed to procure relief. The painful stimuli do not appear to pass along the ordinary sensory pathway. Either this is true or else the pain is central in origin. Cervico-thoracic ganglionectomy has proved of great benefit in treating these cases. In all but the minor cases which recover spontaneously this operation would now appear to be the standard form of treatment for a previously intractable condition.

Trigeminal Neuralgia.—The standard form of treatment for this very distressing disease is by obliteration of the sensory pathway of the affected area. This can be done either by injection or by section of the sensory root of the fifth cranial nerve. In skilled hands these forms of treatment give very satisfactory results in the majority of cases. In a few cases, however, no improvement results and the patient's condition is just as pitiable as before. It is then worth while trying the effect of a cervico-thoracic ganglionectomy. In some few cases dramatic improvement has occurred.

Painful Ulcers—The Pain of Gangrene.—Many ulcers of the extremities, *e.g.* the sole of the foot and the digits, are very slow in healing and are exquisitely painful. They are often pregangrenous mani-

festations. The pain and associated manifestations are similar to that described under Causalgia. The pain of gangrene is very severe and exhausting to the patient. An amputation may be necessary in a case of gangrene of the extremity to relieve the pain when otherwise the surgeon would have preferred to wait for a natural separation.

These cases are often strikingly relieved by the appropriate sympathectomy. The relief of pain is dramatic, and the patient is able to obtain some much-needed rest. Associated with this there is frequently rapid healing of the ulcer or in a gangrenous limb the formation of a clear line of demarcation.

IV. **Symptomatic Group.**—Sympathetic denervation operations find a rôle in various unrelated conditions. This heterogeneous group will now be considered.

Scleroderma.—This is a rare condition as a separate entity, though it may be associated with Raynaud's disease. Changes occur in patches of the skin. These patches become hard and white and painful. The underlying connective tissues are later infiltrated and contractures occur. The condition may be widespread all over the body. No form of treatment previous to sympathectomy was of any real benefit. Definite improvement has been observed after sympathetic denervation, at any rate in the more localized forms.

Chronic Arthritis.—In certain forms of chronic degenerative arthritis pain may be more severe than even the crippling deformity. These are the cases where bony change, apart from atrophy, is slight. The arthritis is mainly periarticular. These cases are sometimes benefited by sympathetic denervation. The method is still experimental and the results are not yet clear. The benefit may accrue by relief of pain, or it may be due to increased vascular supply to the part. This acts as a sort of permanent internal radiant heat.

Retinitis Pigmentosa.—In this condition blindness results from retinal degeneration. Vision from the onset becomes steadily impaired. The retinal vessels become constricted and pigment migrates from the choroid to the perivascular lymphatics. This condition has been treated by sympathectomy, the stellate ganglion being removed. The results have been rather conflicting, many claiming successes while others report no benefit. It would appear that allowing for variations in technique, etc., early cases may be benefited by stellatectomy, and that at any rate this operation should be tried.

Anterior Poliomyelitis.—Trophic changes in cases of severe paralysis cause serious disability. The orthopædic measures necessary for the re-educative exercises in progress may have to be suspended owing to painful chilblains or even ulcers. The child may have to go to bed and splintage become difficult. This is more common in the lower limb and in cases of widespread paralysis. These cases should be subjected to lumbar ganglionectomy. It may be true that the benefit obtained may only last a few years. These years may, however, be vital years of treatment when the orthopædic surgeon will not wish to be hampered by sores.

Hyperidrosis.—Excessive sweating is a well-known manifestation of vaso-motor instability. This sweat may literally drip from such

patients even at room temperature. The condition may be generalized or localized to one area. Sympathetic denervation operations, when properly performed, always lead to paralysis of the sweat glands in the area denervated. In fact, the area denervated can best be estimated by observing the area of loss of sweating. In certain cases of hyperidrosis which do not respond to medical measures, sympathetic operations may be considered. In the rare cases of unilateral excessive sweating sympathectomy is of great value.

Periarterial Sympathectomy.

Sympathetic denervation operations were being performed long before the exact anatomical pathways had been worked out. This was one of the factors which led to confusing results in the earlier investigations. Many surgeons believed that the sympathetic control of the vessels of a limb passed into the limb with the main vessels, and was distributed along the branches of the main vessels to the all-important smaller vessels. Actually this is incorrect. The main vessels entering the limb do have a perivascular sympathetic network which constitutes their own nerve supply, but this does not pass down the limb, branching and subdividing with the smaller vessels. Thus in the lower limb the perivascular sympathetic control ends at about the bifurcation of the common femoral artery. Below this level the sympathetics enter the vessels by twigs from the somatic nerves which have non-medullated sympathetic fibres in them. Hence it is impossible to denervate a limb of sympathetic fibres by performing a periarterial denervation. The discovery of these anatomical facts led to the temporary abandonment of the pioneer operations of periarterial sympathectomy. While it is undoubtedly true that this is a very incomplete procedure and should not be used in, *e.g.*, Raynaud's disease or Buerger's disease, in some other conditions the periarterial operation has its merits. The basis is empirical rather than anatomical. The supreme advantage of the periarterial operation is the ease with which it may be performed and the fact that it can be performed under a local anæsthetic. Elderly patients on whom one would hesitate to perform a ganglionectomy may readily be submitted to the periarterial operation. While the benefit may be only transitory—five weeks to three months—yet this period may be sufficiently long to allow healing of an ulcer or demarcation of a gangrenous area. Again, the periarterial operation relieves pain, though the manner of this relief is not understood. Further, the relief of pain is less transitory than any of the other beneficial effects of the operation, *e.g.* improving the blood-supply. The periarterial operation thus finds its best application in cases of senile gangrene and painful pregangrenous conditions. The periarterial operation may be applied to cases of causalgia, but in this exceedingly stubborn condition the major denervation of cervico-thoracic ganglionectomy is probably preferable.

The Technique of Sympathetic Operations.

The Periarterial Operation.—The vessel (common femoral or axillary is exposed under local anæsthesia for the maximum convenient length The arterial sheath and tunica adventitia are then carefully peele off for a distance of 2 inches or more. The artery will contract unde the mechanical stimulus, but later will dilate. The stripping mus be very thorough, as most of the nerve-fibres are on the deep aspect o the outer coat. Any small strands of tissue must be removed. Th coat of the vessel is then painted with 90 per cent. alcohol to destro any remaining fibres. The only danger of the operation is, of course removal of too much covering with the production of rupture of the vessel, or the production of an aneurism. On the other hand, if too little tissue is removed the patient will not benefit.

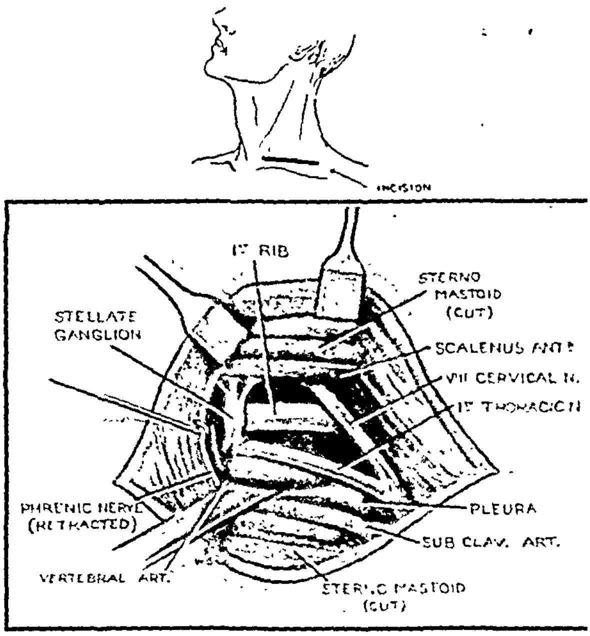


FIG. 193.—THE ANTERIOR APPROACH TO THE STELLATE GANGLION.

Note the relationship to the first rib. Inset shows the skin incision.

Cervico-thoracic Ganglionectomy.—There are two standard methods of approach to the stellate ganglion: the posterior approach (associated with the name of Adson) and the anterior approach. The latter is gaining in popularity, and is the only one to be described here. It will be remembered that to denervate the upper limb the second thoracic ganglion must be removed, together with the stellate ganglion. A collar incision is made just above the clavicle over its inner two-third (Fig. 193). The external jugular vein is divided and the clavicular head of the sterno-mastoid divided until the internal jugular vein is visible. The posterior belly of the omo-hyoid is sough and divided and the scalenus anticus and phrenic nerve defined. The phrenic nerve is then retracted inwards and the scalenus anticus divided at its insertion. This exposes the subclavian artery, which is dissected to free its upper border. The thyroid axis artery is now divided between ligatures near its origin. The subclavian artery is drawn downwards and forwards, and Sibson's fascia is divided along the inner border of the first rib, exposing the pleura: By gauze dissection the pleura is stripped, in a forward and outward manner, of the first three ribs and adjacent vertebræ. The inferior cervica

ganglion should then be seen lying on the neck of the first rib with the trunk of the sympathetic running down on the heads of the ribs away from it. The trunk is hooked up at the level of the third rib and cut across between clips. It is convenient to use silver clips in the deep wound. The trunk is gradually freed upwards by cutting its branches. The trunk is cut across just above the inferior cervical ganglion. The criterion of successful removal is the absence of sweating and the presence of a Horner's syndrome (ptosis of the upper lid, myosis and enophthalmos). It may take some hours for the syndrome to develop. The wound is closed with a small drain left in for forty-eight hours.

Lumbar Ganglionectomy.—There are two alternative methods of performing this operation, *viz.* the extraperitoneal operation and the

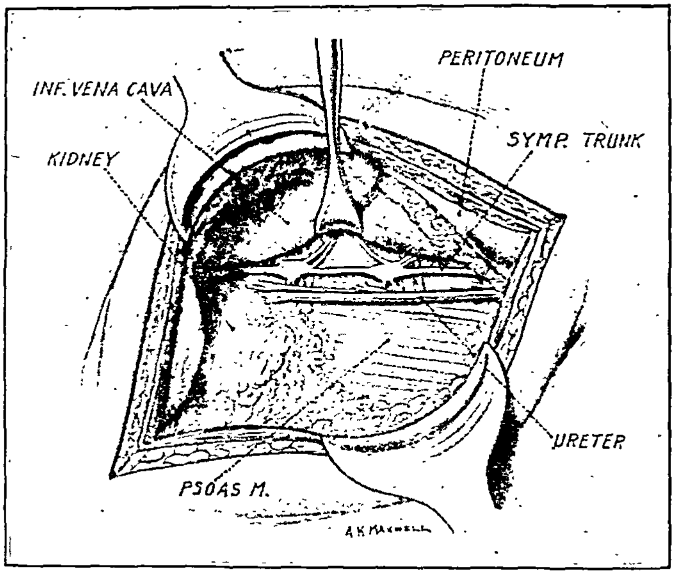


FIG. 194.—THE EXTRAPERITONEAL APPROACH TO THE RIGHT LUMBAR GANGLIONATED CHAIN.

transperitoneal operation. The former is indicated when only one side requires denervation. If both sides require denervation the transperitoneal route is usually employed, unless there is some contraindication to opening the peritoneum, when the extraperitoneal route may be used as two operations usually done in two stages.

(*a*) *The Transperitoneal Approach.*—A full 6-inch left paramedian incision is made from 2 inches above the umbilicus and the abdomen opened. The peritoneum of the posterior wall is incised on the left side lateral to the descending colon and upper part of the sigmoid. The colon is mobilized over to the right. Its blood-supply is carried with it, and also the ureter, which adheres to the peritoneum. The fact should be verified, as on rare occasions the ureter does not come up with the peritoneum. The inner border of the psoas muscle is sought and the lumbar chain is found lying between it and the bodies

of the vertebræ. At the upper end the duodenum may have to be retracted gently to allow access to the second lumbar ganglion. The chain is divided just above the second lumbar ganglion and gradually dissected downwards. Hæmorrhage may be troublesome from small veins, and it is again advisable to make free use of Cushing's clips. The downward dissection ceases at the level at which the ganglionated cord passes behind the iliac vessels. The colon is allowed to fall back into place and the peritoneum sutured. A similar route can then be used on the right side by incising the peritoneum to the outer side of the cæcum and ascending colon, with mobilization of the gut inwards. Then proceeding as on the left side, the ganglionated chain is found lying between the inferior vena cava and the vertebral bodies. To save displacing so much gut a more direct approach may be used on the right side (Fig. 194). The root of the mesentery is identified and an incision made just to the right of it over the vena cava. Care has to be taken to avoid the spermatic vessels, the ureter, the vessels in the mesentery, and the duodenum. The inferior vena cava is identified and retracted, and the operation proceeds in the usual manner.

(*b*) *The Extraperitoneal Route.*—A Mayo incision similar to that used for nephrectomy is made and the incision deepened until the psoas muscle is reached. The peritoneum is stripped inwards and forwards, carrying the ureter with it (Fig. 195). The inner border of the psoas is defined, and on the right side the inferior vena cava. The sympathetic trunk is searched for lying on the lateral aspect of the vertebræ.

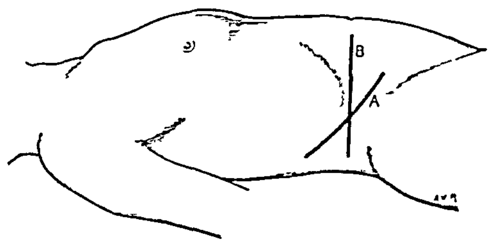


FIG. 195.—INCISIONS WHICH MAY BE USED IN THE EXTRAPERITONEAL EXPOSURE OF THE LUMBAR GANGLIA.

A, Unilateral approach; B, bilateral approach.

Presacral Neurectomy.—A right paramedian incision is made centred on the umbilicus. The abdomen is opened and the viscera examined. The patient is tilted into a high Trendelenburg position and the intestines packed off upwards and leftwards. The interiliac triangle made by the two common iliac arteries, the bifurcation of the aorta, and a horizontal base at the level of the sacral promontory is defined. The peritoneum over the centre of the triangle is picked up, incised vertically, and the bifurcation of the aorta exposed. Starting in the mid-line at the level of the sacral promontory, the dense connective tissue about 1 inch wide is dissected off the anterior aspect of the fifth lumbar vertebra up to the bifurcation of the aorta. The dissection is strictly mid-line, and on no account must it diverge to the left, as this would include the parasympathetic motor supply to the colon and rectum. The strip of connective tissue removed contains the presacral nerve. The posterior peritoneal incision is closed, and then the packs removed and the abdomen closed in layers.

CHAPTER XVII.

SURGICAL DISEASES OF THE SKIN AND OF THE CUTANEOUS APPENDAGES.

A **Boil** or **Furuncle** is a localized inflammation of the skin, usually terminating in suppuration, due to infection with staphylococci of a hair follicle or sebaceous gland. Experimentally, a plentiful crop of boils can be produced by rubbing a culture of staphylococci into the skin, and clinically a similar infection is the most common cause of this condition. The secondary or satellite boils which form around a primary one are due to the friction upon the healthy integument of dressings, covered with pus and microbes.

People with coarse skins and a tendency to comedones are specially liable to the occurrence of boils, but some depressing constitutional condition, such as chronic Bright's disease or diabetes, is often present in patients who suffer from recurrent crops of boils. A gangrenous inflammation ensues after infection, resulting in the death of the hair follicle, or of the sweat or sebaceous gland involved, and of the surrounding connective tissue, and the slough thus formed is cast off by a process of suppuration. A matured or ripe boil, therefore, consists of a central slough or core, a zone of pus around it, and external to this granulation tissue merging into healthy skin and connective tissue.

Signs.—A boil commences as a small red irritable pimple, from which a hair may often be seen to protrude; it increases gradually in size, becoming more and more painful, until it forms a conical tumour, deep red in colour and exquisitely tender. A small whitish spot appears in the centre, and around this so-called core yellow pus can be seen. Finally it bursts, discharging the pus, and subsequently the core or slough comes away. The process is then at an end, and the wound rapidly heals by granulation. Occasionally the inflammation extends more deeply into the subcutaneous tissues, constituting a 'carbuncular boil.' Lymphangitis sometimes follows, and the neighbouring lymphatic glands may become enlarged and painful, but rarely suppurate. A boil sometimes subsides without suppuration, leaving the parts thickened and infiltrated, the condition then being known as a 'blind boil.'

Treatment.—Many boils may be left to burst naturally, though possibly the process may be checked by painting them twice daily with iodine (2 per cent.) and applying Klapp's suction-glass two or three times a day. Where pus has formed an incision is made, and the suction-ball persisted in till the slough has come away. In the later stages the skin around should be thoroughly purified, and the pus

and core received on portions of wool soaked in carbolic lotion (1 in 20), and the cavity lightly swabbed out with pure carbolic acid. A small collodion dressing is then applied. Tonics, such as iron and quinine, are usually required, except in plethoric individuals, in whom a spare diet and abstinence from stimulants may be recommended. A change of air to a bracing seaside place is often advisable, especially when a succession of boils has appeared. In the more persistent cases a staphylococcal vaccine may be employed with advantage, and the boils will in some cases be cured or aborted (p. 9). In others the vaccine seems to do but little good, and then stannyoxyl may be employed, or injections of collosol manganese ($\frac{1}{2}$ to 2 c.c.) every three or four days; excellent results have been reported in many cases, but it is not infallible.

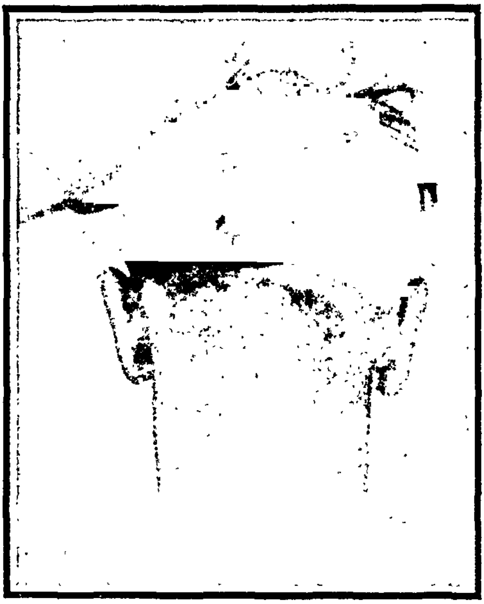


FIG. 196.—LARGE CARBUNCLE AT THE BACK OF THE NECK.

A **Carbuncle** is a more extensive infective gangrene of the subcutaneous tissues, due to a local invasion with pyogenic microbes, the commonest being the *Staphylococcus pyogenes aureus*. It occurs in individuals run down by any general debilitating condition, such as albuminuria or diabetes, in whom the germicidal powers of the tissues are much depreciated; it is also occasionally met with as a sequela of acute fevers. The exciting cause may be some blow or squeeze, resulting in extravasation of blood or some local diminution of vitality; into this area cocci are implanted either by auto-infection, or more usually through the sweat glands or hair follicles, or through some slight superficial abrasion.

Signs.—A carbuncle commences as a hard, painful infiltration of the subcutaneous tissues, the skin over which becomes red and dusky. The swelling gradually increases in size in all directions, until a diameter of many inches may be reached. As it extends peripherally the central parts, which were formerly brawny, become soft and boggy, and the overlying skin shows evidences of yielding to the pressure within. Vesicles form on the surface, and finally pustules; these in turn burst, and allow a tardy exit to the ashy-grey sloughs and purulent discharge accumulated below (Fig. 196). Fresh openings gradually develop, leading to a cribriform condition of the cutis; some of these apertures enlarge and run into one another, producing a central irregular crateriform opening, at the bottom of which lies the necrotic tissue. As the violence of the inflammation subsides the sloughs gradually separate, leaving a clean granulating wound. Carbuncles most frequently occur on the back, the nape of the neck, the shoulders,

and nates, where the vitality of the tissues is never very active; when they form on more vascular parts, such as the face and lips, the consequences may be even more serious, since infective thrombosis of the large veins may follow, and this may quickly spread up to the cavernous sinus. The soft and spongy tissue of the cheek is a very favourable place for the extension of the necrotic process, and there may be a wide area of mischief under an apparently insignificant superficial lesion. A carbuncle is usually single, and may be accompanied by lymphangitis and a painful enlargement of the nearest lymphatic glands.

There is often considerable constitutional disturbance of an asthenic type, although the temperature is not necessarily much raised. A temporary glycosuria of toxic origin is sometimes present, and disappears as the condition improves, but occasionally pyæmia or septicæmia may supervene.

Treatment.—In the early stages Bier's treatment by induced hyperæmia may be successful in preventing suppuration, but where the organisms are at all virulent or the focus large it will probably fail. Attention should always be directed to the possible presence of coexisting disease. A thorough physical examination is made with a view to finding any debilitating condition contributing to the lowered resistance of the patient. The heart, lungs, and alimentary tract should receive careful attention; the urine should always be tested, particularly for sugar, acetone, and albumen. Local relief is obtained to some extent by applying hot fomentations every two hours. A magnesium sulphate paste* applied over the carbuncle often gives relief, increases the flow of lymph, and facilitates the liquefaction of the slough.

Operative treatment may be required in some cases. An incision is made through the whole length of the diseased area, cutting to the limit of its depth; a second incision is made through its breadth, crossing the first at a right angle in the centre of the carbuncle. The points of the four flaps so defined are cut with sharp scissors near their base, and as much as possible of the necrotic tissue is dissected away. Hæmorrhage may be considerable at this stage, but it may be controlled by firm pressure and packing with gauze. The base and the walls of the cavity are lightly touched with a pledget of wool soaked in pure carbolic acid. The cauterizing effect of the acid is shown by the manner in which it arrests oozing from the cut vessels; it also has the merit of destroying any active organisms which may have survived curetting with the knife or spoon. It has been observed, however, that it sometimes increases the amount of subsequent sloughing. The cavity is packed tightly with cyanide gauze, care being taken not to invert what remains of the flaps. An abundant dressing of sterile gauze and soft wool is applied, and the operation completed by a tight bandage, which should be ample enough to immobilize the affected part. Good food, iron, and quinine must be administered,

* Mag. sulph.	45 ounces.
Glycerin	55 ,,
Phenol	0·5 ,,

whilst appropriate treatment by insulin and limitation of diet are necessary in diabetic patients.

A **Corn** (*clavus*) is a localized outgrowth of the epidermic layer of the skin, together with a central ingrowth of a hard, horny plug, which compresses and causes atrophy of the underlying papillæ, constituting a cup-shaped hollow, whilst the surrounding papillæ are hypertrophied. The presence of this central plug constitutes the difference between a true corn and a simple callosity or diffuse overgrowth of the epidermis. Any abnormal pressure is capable of producing either condition, granting that it is not sufficiently severe or intense to lead to ulceration; but corns seldom occur except on the feet, and the chief cause is badly-fitting boots. Two varieties are described, *viz.* the hard and the soft.

The **hard corn** usually occurs on the little toe, or over the head of the metatarsal bone of the great toe, or over the heads of the first phalanges of the other toes, especially if there is any tendency to hammer-toe. They form more or less conical swellings, with a dark, dry, central plug, and are often very painful, especially when rain is threatening. Suppuration sometimes occurs beneath a corn, and the pain then becomes acute. If it is not attended to early, the pus may burrow and cause necrosis of deeper parts or a destructive arthritis. **Treatment** consists in paring the corn, after softening with hot water, or treating with salicylic acid plaster (10 or 20 per cent.), or painting with a solution of salicylic acid in collodion. A ring of felt plaster may subsequently be worn, but attention must be directed to the boots, and the cause of the trouble removed. Occasionally, where the toe is deformed, or disease of the bones or joints has developed, it is necessary to perform amputation.

A **soft corn** occurs between the toes, and owing to the absorption of sweat the surface looks white and sodden; it is often extremely painful. **Treatment** consists in removing the thickened cuticle after the use of salicylic acid. The parts are very carefully cleansed night and morning, and spirit of camphor painted on at night, whilst cotton-wool is worn between the toes during the day. Failing this, the corn must be removed by operation. The toes are held widely apart, and the incisions run transversely between them, so as to include the corn. The wound can be readily closed by sutures.

Tulip Fingers.—Although this condition has been known in Holland for centuries, it is only of recent years that it has occurred in England. The ætiology is unknown, but trauma plays a part and probably a bacterial infection follows. Tulip fingers occur in women who handle, cut and grade the bulbs. An infection of the nail-bed occurs, and the nail separates. At times subungual abscesses form.

Treatment is difficult, but the application of a spirit solution of hydrarg. biniod. (1 in 1,000) is useful as a prophylactic when the condition has occurred. It should be applied each day on wool before starting work.

Perforating Ulcer of the Foot forms on some parts of the sole, and progresses deeply so as to involve sooner or later the bones and joints.

It is usually due to two main factors, *viz. anæsthesia* of the sole, and more or less persistent *traumatism*, such as arises from wearing a tight boot or from the presence of a nail, which is not noticed owing to the concurrent anæsthesia. It is therefore likely to be met with: (1) In certain central nervous diseases, *e.g.* tabes dorsalis, syringomyelia, spina bifida, etc.; (2) in diseases such as diabetes, syphilis, alcoholism, etc., which lead to peripheral neuritis; and (3) as a sequence of traumatic lesions of the nerves affecting any portion of their course from the spinal cord downwards. (4) Perforating ulcer is occasionally due to pure plantar lesions, apart from any nervous influence—*e.g.* a suppurating wart or corn, or even a chronic epithelioma. The skin under the head of the first metatarsal is the part most frequently affected, but any spot to which undue pressure is directed may become involved, and not uncommonly several such sores may be seen on the same foot. A corn or callosity first forms, and under this a bursa, in which suppuration takes place; the pus, finding a difficulty in coming to the surface owing to the thickness of the cuticle, spreads deeply into the soft structures of the sole, and the suppuration may even involve bones and joints. A typical perforating ulcer presents the appearance of a sinus passing down to the deeper parts of the foot, and even extending through to the dorsum; the orifice is surrounded by heaped-up and thickened cuticle (Fig. 197). There is sometimes but little discharge and often no pain, but when bones or joints are affected free suppuration may occur. If allowed to progress without treatment, the bones and joints of the foot may be destroyed extensively, or may be welded together into a solid painful mass, in either case necessitating amputation. A cure can sometimes be determined in the early stages by removing the thickened mass of cuticle and purifying or excising the sinus; the cavity thereby formed is packed with gauze and allowed to heal by granulation. Periarterial sympathectomy is useful in many cases, but should it fail, or if bones or joints are involved, amputation will be required.

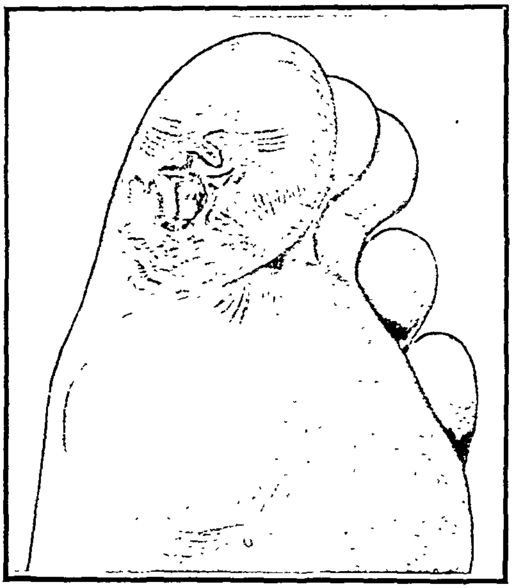


FIG. 197.—PERFORATING ULCER OF GREAT-TOE PENETRATING TO BONES AND CAUSING NECROSIS.

A **Wart** (*verruca*) is a papillary overgrowth of the skin, appearing as a horny projection about the size of a split pea, and usually seen on the hands of young people; its surface may be smooth or irregularly filiform, and its colour varies with the amount of dirt ingrained on

the surface. When smooth-topped they are sometimes extremely numerous, and may be a little difficult to distinguish from lichen planus. In parts where there is a certain amount of noisture warts become soft in character (Fig. 198), and form large vascular masses, *e.g.* venereal warts. The best method of treating ordinary warts is to paint them with glacial acetic acid, or some other caustic, every two or three days, after softening and removing the horny crust with salicylic acid. Ionic treatment with salicylates is also of value.

FIG. 198.—LARGE WART OF THE FOOT OF SIX YEARS' DURATION.

Verruca Necrogenica (see p. 244).

A **Chilblain** (*pernio*) is an inflammatory hyperæmia, usually involving the fingers, toes, or ears, and determined by exposure to cold. It is generally seen in young people with defective circulation, whose fingers and toes easily 'go dead.' They are very apt to occur on paralyzed limbs. After the period of anæmia and pallor the part begins to itch or burn, and becomes red, swollen, and shiny. Exudation occurs into and beneath the skin, and in bad cases a blister with blood-stained contents forms; when this bursts, troublesome ulceration ensues. To prevent the formation of chilblains the patient's circulation must be improved, and exposed parts kept warm. A course of lactate of calcium is helpful; 5 grains t.d.s. are administered the first week, 10 grains during the second week, and 15 grains during the third, followed by a suitable tonic. In the earlier stages treatment by induced hyperæmia is most valuable; an elastic bandage may be worn for six hours or so daily, whilst locally the parts may be painted with tincture of iodine or a solution of ichthyol. When the chilblain breaks, simple antiseptic precautions may suffice, but a more stimulating application is usually required, and Peruvian balsam or resin ointment will be found useful. In paralyzed limbs, or cases otherwise intractable, galvanic baths will usually prevent the development of these troublesome lesions.

Tuberculous Affections of the Skin.—**Lupus Vulgaris** is a chronic inflammation of the skin of tuberculous origin. It is met with in children and young adults, rarely commencing after the age of thirty. Its most usual situation is the face, generally starting on the nose or cheek (Figs. 199 and 200). It is rare on the scalp, but fairly common on the trunk and extremities. The mucous membrane of the nose and mouth is also attacked, but usually by extension from the skin. It is not often symmetrical, except when commencing on the nose.

Clinical Features.—The earliest manifestation of lupus consists in the formation of one or more shot-like nodules in the deeper layers of

the skin, which are surrounded by a zone of hyperæmia and infiltration. These nodules are not particularly hard to the touch, but when of any size can be demonstrated to be of a brownish-orange tint, especially if they are devascularized by the pressure of a glass slide, and then the colour somewhat resembles that of apple-jelly. Gradually the process extends, and usually more rapidly in one special direction, following the course of the vessels. At the same time the integument becomes infiltrated and transformed into granulation or cicatricial tissue, covered by a layer or two of epithelium (Fig. 199), and owing either to degeneration of the tuberculous nodules or to a lack of vitality, arising from compression of the vessels by the contraction of this new formation, ulceration is very liable to follow (Fig. 200). In the extremities the lupoid growth not unfrequently takes on a warty aspect, somewhat similar to the 'anatomical wart' occasionally seen on the knuckles of post-mortem porters (p. 244).

FIG. 199.—NON-ULCERATING LUPUS OF CHEEK.

FIG. 200.—ULCERATING LUPUS OF NOSE AND CHEEK.

A *Lupoid Ulcer* usually spreads at one margin as it heals at the other, and hence under typical circumstances is more or less crescentic in shape. The surface is covered with granulations, often of a protuberant nature. The edges are raised and infiltrated, and scattered lupoid tubercles are readily distinguishable extending into the healthy tissues, which are usually red and congested. A considerable amount of sero-pus is often secreted, and this by drying forms thick scabs. Any cicatrix which results from natural processes of cure is thin and vascular, easily breaking down from slight irritation. The process extends gradually, with or without intermissions, from the seat of its first appearance; it is as a rule limited to the cutaneous tissues, but when it attacks the nose, the cartilages are often involved and destroyed, whilst if it involves the palate or septum nasi, perforation is very likely to follow. The disease is almost painless, and does not at

first affect the general health. Neighbouring lymphatic glands may become inflamed, and in a few instances are the seat of a tuberculous deposit. Left to itself, it usually comes to an end sooner or later, the ulcerated parts cicatrizing, but leaving indelible traces of its ravages in the shape of obvious scars, with often considerable loss of substance. Occasionally it persists in spite of treatment, and then an epithelioma may in time develop on the site of the mischief, running a rapid course owing to the vascularity of the part.

Pathological Anatomy.—The characteristic microscopical feature of lupus lies in the formation of nodules around the smaller vessels of the skin, consisting chiefly of a mass of round cells, within which may perhaps be observed a giant cell and endothelioid cells, arranged in the same way as in tubercle.

The **Diagnosis** of lupus from syphilitic and other destructive affections of the skin turns on the presence of outlying nodules beyond the spreading edge of the lesion, together with the apple-jelly-like granulations, and the thin, congested character of any cicatricial tissue present, whilst the slow, though continuous, progress and the tendency to heal at one part as it spreads at another are also suggestive of its presence. The age and constitution of the individual, the absence of the Wassermann reaction, and the persistence of the disease in spite of treatment, must also be taken into account.

In the **Treatment** of lupus reliance is now placed almost entirely on *heliotherapy* (p. 299), both local and general, or on exposure to the ultra-violet rays of a *carbon-arc light*. The *Finsen light* (p. 299) similarly has curative powers. In the latter each sitting lasts for one and a quarter hours, and an attendant whose eyes are shielded by dark glasses controls the crystal water-chamber, keeping it firmly against the skin, and slightly shifting it from time to time, so that an area as large as a shilling may be acted upon at each séance. Slight inflammatory phenomena follow, and a local leucocytosis supervenes, as a result of which the disease disappears, and a soft supple scar is produced, which is often very little obvious. This type of treatment has been found of most value where ulceration is absent and the patch of no great size. *X-ray treatment* plays its part in the treatment of lupus. The same precautions as to the protection of healthy tissues must be taken as for cancer (p. 305). The best results have been observed by using a tube of comparatively low vacuum, and by working for a definite inflammatory reaction; when this has disappeared, the treatment is repeated. The length of the course necessarily varies, but as a rule three to six exposures a week of not more than ten minutes each will suffice. The X-rays act best on the ulcerative and fungating forms of lupus, which clear up and heal; but after this has been secured their action must cease, partly because they have no influence upon the small nodules of disease which remain entangled in the scar-tissue, and also because their prolonged action might terminate in the appearance of epithelioma. For these nodules the Finsen or arc light treatment should be employed.

When treatment of this type cannot be obtained, or where in spite of improvement nodules of the lupoid material persist, the lesions

may be dealt with by scraping with a lupus spoon, and subsequently applying solid nitrate of silver, acid nitrate of mercury on a match-end, chloride of zinc as a paste, solid powdered permanganate of potash, or even the actual cautery. A pointed diathermic cautery is also useful for digging out and destroying localized lupus nodules. Certain drugs may also be used to cause necrosis of the nodules in the diseased tissue, of which the best is pyrogallol, applied in a 10 per cent. ointment (Whitfield).

Lupus Erythematosus is a disease the nature of which is not yet satisfactorily determined. The appearance of the affection is tolerably characteristic; it is usually situated on the face, and in the most typical cases symmetrical patches are formed over the root of the nose and cheeks, corresponding in appearance to a butterfly with outspread wings. The condition frequently invades the forehead, ears, and scalp, and occasionally appears on the trunk, being then unilateral. It appears as a smooth hyperæmic surface, covered with a branny desquamation; the scales consist of inspissated sebum, and are continuous with deep plugs, which can be traced into the mouths of enlarged sebaceous follicles. As the disease spreads peripherally, the older and central portions are transformed into cicatricial tissue of a pale, thin and white type, in marked contrast to the hyperæmic condition of the advancing margin. It is usually seen in adults, and more frequently in women than men. Progress is exceedingly slow, and ulceration uncommon except when the ears or scalp are involved; in the latter region the hair is often lost. Epithelioma has also been known to follow this affection.

The **Treatment** consists in attention to the general health, together with the local application of weak tarry and mercurial preparations. The X-rays and Finsen light act rapidly, but must be used with caution, since the inflammatory disturbance caused by them is considerable.

Affections of the Nails.

A **Paronychia** (panaritium, or 'run around') is a condition frequently seen in surgeons, nurses, or others who have to expose their hands to infective material, as a result of infection of the semilunar fold at the base of a nail. It is often preceded by a 'hang-nail,' which gives entrance to the organisms, and the patient's general condition may be unsatisfactory; not uncommonly, however, it is seen in hospital nurses and others who have just returned from a holiday, suggesting that they need to become immunized to their surroundings. The skin at the side of the nail is swollen and hyperæmic, and on pressure is tender to the touch; gradually the pain increases and is particularly troublesome at night, perhaps preventing sleep. A certain amount of discharge may occur through the semilunar fold, but a sufficient exit is rarely given by natural processes. Unless effective treatment is undertaken, the suppuration spreads around the root of the nail to the other side, and also burrows beneath the nail, separating it from the matrix. Granulations spring up freely from the semilunar fold, and thereby discharge is often prevented from escaping.

Treatment in the early stages is by fomentations and the induction of passive hyperæmia by the application of Martin's bandage to the arm; the skin at the side of the nail is pared down, and if pus appears, an incision parallel to the basal margin of the nail through the inflamed tissues will give exit to the pus, and often suffices to cure the case. If the pus has burrowed beneath the nail, one or more incisions must be made radially through the semilunar fold so as to expose the base of the nail, and permit all the loosened portion to be cut away from the matrix by sharp scissors; in some cases all the base of the nail has thus to be sacrificed. The terminal portion may, however, be left, as it is serviceable while the new nail is forming. Abundant granulations spring up from the matrix, and these may need to be kept in check by nitrate of silver.

Ingrowing Toenail is an ulcerated condition of the soft parts projecting over the side of one of the toenails (usually that of the great-toe), and due either to the pressure of pointed or badly-fitting boots,

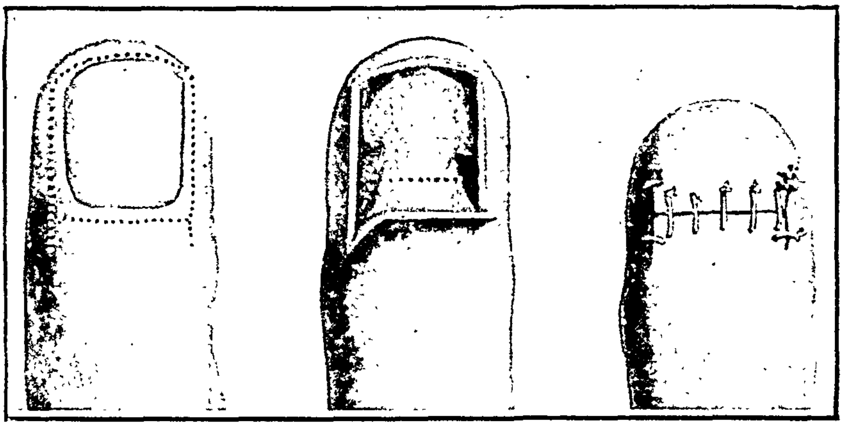


FIG. 201.—OPERATION FOR INGROWING TOENAIL BY REMOVAL OF NAIL BED AND PORTION OF TERMINAL PHALANX.

or to neglect in trimming the nails. The fold of skin is thus pressed by the boot over and against the nail when the patient walks, and in order to diminish the pain and irritation caused thereby, he often cuts away the projecting angle of the nail, but leaves a deep corner, which still further irritates the soft parts. Ulceration ensues, accompanied by an offensive discharge and so much pain as to prevent the patient from walking. The matrix of the nail may also become inflamed, and onychia result. In the earliest stages, further progress can often be prevented by careful attention to the nails, by the use of square-toed boots fitting easily, and by introducing small plugs of aseptic wool to press back the overhanging fold of skin. A cure can sometimes be effected by excising an oval portion of skin from the side of the toe and close to the nail. The edges of the incision are drawn together by horsehair, and thus the overgrowing fold of skin is drawn away from the nail. It is more satisfactory, however, to excise the overhanging fold of skin completely so as to expose the side of the nail, which can also be cut away, if necessary, together with

the projecting angle. This latter treatment must always be adopted when ulceration and suppuration are present. In those cases where the condition tends to recur, it is advisable to remove the whole nail-bed, excise the distal portion of the terminal phalanx, and close the wound completely as in Fig. 201. This always results in a permanent cure.

The term **Onychogryphosis** is applied to a hypertrophic condition of the nails, which become distorted and bent, or twisted up, perhaps simulating a ram's horn. It is usually limited to the great toes of elderly people, and is due to neglect. The nails are very rough, and often covered with grooves or ridges, whilst beneath them is an accumulation of soft, offensive epithelium. The only treatment is removal.

Affections of the Sebaceous Glands.

Sebaceous Cysts occur in any part of the surface of the body, but especially the scalp, and are due to obstruction of the duct of a sebaceous gland. They are rounded swellings, firm and elastic to the touch, movable on the deeper structures, and always attached at one spot to the skin. On careful examination the obstructed mouth of a sebaceous follicle can usually be seen, and possibly some of the contents of the sac squeezed through this opening. The cyst wall is formed by several layers of epithelium, surrounded by dense fibro-cicatricial tissue, and if exposed to irritation or pressure, as when situated on the back or shoulder, and rubbed by the braces, becomes very firmly adherent to the surrounding parts. The material contained within is of a cheesy, pultaceous consistency, with a peculiar stale odour, yellowish-white in colour, and under the microscope is seen to be composed of fatty and granular débris, epithelial cells, and cholesterine. Left to themselves, the cysts may attain considerable dimensions, whilst the walls and contents sometimes become calcified. Occasionally the exudation oozes through the duct, and dries on the surface, with just sufficient cohesion to prevent it from falling off; layer after layer of this desiccated material is deposited from below, finally giving rise to what is known as a **Sebaceous Horn.** These become dark in colour from admixture with dirt, and are always more or less fibrillated in texture; the base, to which they are firmly adherent, is infiltrated and hyperæmic. Sebaceous cysts sometimes inflame and suppurate; sooner or later they burst or are opened, and then the process subsides. They may be cured in this way, but more frequently the cyst fills up again, and the same series of phenomena are repeated after an interval. Should the contents only escape partially, the remainder is liable to undergo putrefactive changes, giving rise to an offensive ulcerated surface with raised edges, which may readily be mistaken for epithelioma. It is sometimes known as *Cock's Peculiar Tumour*. True malignant disease of an epitheliomatous nature is said occasionally to supervene.

Diagnosis.—From a *dermoid cyst* it is known by the facts that the dermoid is congenital in origin, that it is limited to certain localities, whilst it is hardly ever directly attached to the skin. From a *fatty*

tumour it is recognized by its rounded shape, its fixity to the skin, the absence of lobulation, and by its more solid character, whilst a lipoma is softer and more movable. From a *chronic abscess* it is distinguished by the dilated orifice, by its firmer consistency, and by the history.

Treatment.—A sebaceous cyst should be entirely and completely removed if giving rise to any disfigurement, inconvenience, or pain. In the scalp all that is needed is to transfix the tumour, squeeze out the cheesy contents, and then the cyst wall can be readily removed by grasping it with dissecting forceps and pulling it away. In other situations the cyst wall may require to be dissected out; but even then it is advisable to open it by transfixion, and to deal with the sac from within. Horns and fungating ulcers should be excised with the surrounding skin.

Occasionally a true **sebaceous adenoma** develops in connection with these cysts. It may be slowly-growing and of a firm, solid consistency; but sometimes it is much more vascular and grows rapidly. The latter has a form of semi-malignancy in that it is very liable to recurrence, and has therefore often been mistaken for a sarcoma. On microscopic section it closely resembles a rodent ulcer, but its clinical history is quite distinct. Its most frequent situation is the scalp, and it requires to be removed with a free hand, the defect in the scalp being made good by Thiersch-grafting.

Molluscum Contagiosum.—This affection shows itself in the form of a number of firm hemispherical nodules, a little larger than a split pea, usually of a yellowish-white colour, and very definitely umbilicated. The depression in the centre may be occupied by dry débris, and from the larger ones a waxy mass can be expressed. They are usually seen on the face, but may involve any part of the surface of the body. There seems no doubt as to their contagious properties, this being perhaps best seen in the development of growths of this nature on a mother's breast, secondary to those on the face of her baby, but the cause of the contagion is by no means certain. Pathologically, the tumours consist of numerous wedge-shaped lobules of polygonal, nucleated, epithelial cells, supported by a fibrous stroma. The cells towards the centre undergo a waxy or hyaline degeneration, and in them are seen numerous rounded bodies, which have been supposed to resemble psorosperms. *Treatment* consists in cutting or pulling them away, or in cutting them across, and squeezing the contents out from the well-defined capsule.

Rodent Ulcer (basal-celled carcinoma) is a special variety of glandular cancer, commencing either in the sebaceous glands or in the basal layer of the rete Malpighii. It is usually met with in elderly patients, though occasionally observed in those under forty, and is seen with special frequency on the upper two-thirds of the face, the skin below the inner and outer canthi being the chief seats of election. It commences as a papule or flat-topped nodule in the skin, surrounded, perhaps, by an area of hyperæmia. The infiltration extends gradually in all directions, but the ulceration usually keeps pace with the new growth. The ulcer has a smooth but somewhat depressed surface, is

perhaps covered with granulations, and bounded by a slightly raised, indurated, rolled-over edge (Figs. 202 and 203). In most cases one can detect evidences of the new formation beneath the skin beyond the edge. If kept aseptic there is but little discharge, and imperfect attempts at cicatrization are often observed, the scar, however, readily breaking down; but when septic, the surface is covered with sloughs, and an abundant offensive discharge escapes. The condition is painless; neighbouring lymphatics are not enlarged, and the general health does not suffer, except in the later stages. The progress of the case is slow, but continuous, and although it spreads for a time superficially rather than deeply, sooner or later underlying structures become involved, and then nothing hinders the destructive process, even the bones of the skull being eroded and the dura mater exposed.

FIG. 202.—RODENT ULCER OF MANY YEARS' STANDING.

FIG. 203.—LARGE RODENT ULCER OF FIFTEEN YEARS' STANDING.

Microscopically, the growth consists of interlacing columns of epithelial cells, interspersed with fibro-cellular tissue (Fig. 204). The constituent cells are small, globular, and closely packed, never of the 'prickle-cell' type, and rarely show signs of keratinization; hence 'cell-nests' are uncommon, although they are sometimes observed. The cells of the peripheral layer, however, are often elongated and arranged side by side like a palisade. The deep processes spread laterally rather than deeply beneath the unaffected skin, the papillæ of which are atrophied; their outline is clearly defined, and frequently angular on section. There is but little infiltration of round cells around the epithelial columns.

Treatment.—There are only two efficient methods of dealing with rodent ulcer, *viz.* excision and radio-therapy; the use of caustics has been entirely superseded. Where possible, the method of choice consists in free *excision*, a margin of at least half an inch all round

being allowed; the defect is then made good by neat suturing, skin-grafting, or some plastic operation. Inasmuch as the most frequent site of the trouble is the face, the ultimate æsthetic effect must be most carefully considered.

Radio-therapy by means of X-rays or radium is on the whole more satisfactory in the great majority of cases. Formerly observers used massive doses at long intervals, but it is beginning to be realized that

FIG. 204.—RODENT ULCER.

a continuous series of small doses produces better results. A complete healing of the part may follow, with disappearance of all the thickening, but recurrence is not uncommon, and then a repetition of the irradiation is often unsatisfactory. The influence of the rays upon the healthy cells of the part is of a depressant character, and hinders them from taking their due share in the reparative process which is essential.

CHAPTER XVIII.

AFFECTIONS OF MUSCLES, TENDONS, AND BURSÆ.

Injuries of Muscles and Tendons.

Contusion.—Muscles are bruised as a result of blows or falls, leading to more or less extravasation, with possibly some rupture of the fibres. The part becomes tender and swollen, and any active contraction gives rise to pain; passive movement, however, is tolerated if the injured fibres are not thereby put on the stretch. Fomentations and rest may be needed for a few days; but regular massage, and perhaps elastic support, are subsequently necessary.

Sprains and Strains, due to violent efforts or falls, result in the tearing or stretching of some of the fibres. Considerable pain and stiffness follow, especially in rheumatic and gouty patients. Rest and firm pressure should be used at first, to minimize effusion or to ensure its absorption. The limb must be placed in such a position as to relax tension on the injured part, and often a pad or firm bandage over the tendon at a little higher level will steady it and enable it to be used without pain. Elastic pressure, massage and the alternate application of hot and cold water will do much to ensure complete recovery, which is most important, especially in subjects liable to rheumatism or tubercle.

Bowler's Arm.—This condition is due to a strain of the coraco-brachialis or the long head of the biceps, and often occurs after a long spell of fast bowling, manifesting itself at the end of the day when all movements of the arm appear to be painful.

Absolute rest from bowling for at least two weeks is essential, during which time massage and active movements should be encouraged.

Tennis Elbow falls into this category. It is usually due to a strain of the pronator radii teres, induced by a sudden twist of the forearm in the effort to put 'top spin' on the ball, and occurs most commonly in the earlier part of the tennis season, before the muscles have become habituated to the unusual exercise. Aching pain is experienced in the front of the forearm, and efforts at active pronation are agonizing. Complete rest from the game for a time is essential, and the pressure of a firm bandage or strapping over the painful part desirable; massage and remedial exercises are subsequently required.

Tennis Leg, although an unfamiliar condition in this country, is well known in America. The term is used for defining a group of injuries characterized by slight or more serious damage to the muscles, tendons, and aponeuroses forming the triceps cruris. Under it are also included injuries caused by a violent strain of the plantaris tendon. Early fixation in full plantar flexion is the treatment to be adopted, followed

by the use of a high-heeled boot when the patient begins to walk about.

Rugby Wrist.—This is due to a bruising of the triangular fibro-cartilage which separates the lower end of the ulna from the wrist-joint, and is caused by handing off with the ulna side of the hand. Movements of the wrist-joints are painful and restricted.

The **Treatment** consists of deep massage combined with diathermy. Recovery may be expected within three weeks.

Trigger Finger.—Although this condition may be congenital, it is far more often traumatic in origin, and is the result of a sprain of the finger. The condition occurs chiefly in manual workers, particularly women. When the patient attempts to straighten the finger from the flexed position, she finds that this can only be managed with an effort and the finger finally snaps straight. The tendon sheath should be opened and the thickened portion of the sheath removed.

Snap Thumb.—This is an allied condition to trigger finger, in which there is an obstruction to the free movement of the long flexor tendon of the thumb, caused by a thickening of the sheath as it passes between the two sesamoid bones at the metacarpo-phalangeal joint.

Treatment consists in incising the tendon sheath, which allows free movement of the tendon.

Rupture of the Sheath of a muscle is an accident occasionally met with, especially in the adductors and rectus abdominis. The belly of the muscle, when relaxed, protrudes through the opening as a hernia, constituting a soft semi-fluctuating swelling. In treating this condition the limb must be kept at rest in such a position as to relax the muscular fibres and allow the rent in the fascial sheath to heal. In old-standing cases it is justifiable to cut down upon and expose the opening in the muscular sheath, the edges of which are sutured together, or if this cannot be effected a graft of fascia lata may be stitched over the defect.

Displacement of Tendons rarely occurs except in parts where these structures pass through osseo-fibrous canals, and particularly in those where the line of action is thereby changed. During some violent effort the patient feels a sudden localized pain, followed by a certain amount of limitation of mobility. This accident is popularly known as a 'rick.' In superficial parts the displaced tendon can sometimes be distinctly felt in an abnormal position, and this becomes more evident on attempting to move it. Thus the long tendon of the biceps may be dislocated from the bicipital groove; and various tendons about the wrist or ankle, especially that of the peroneus longus, may similarly suffer. If left alone, the parts settle down more or less comfortably, but some permanent weakness may persist; recurrence is very likely to ensue if movement is permitted before the newly-formed connections have had time to consolidate.

Treatment consists in fully relaxing the muscles and replacing the tendon, if possible, by manipulation. The parts are then immobilized for six or eight weeks by a plaster of Paris splint or strapping. If the displacement recurs, it is sometimes advisable to expose the tendon and stitch it back into position, using early passive movement to

prevent the formation of troublesome adhesions. This is required most frequently in the case of the peroneus longus tendon, which slips forwards from its groove behind the external malleolus. The external annular ligament is thereby ruptured, and the operation consists either in suturing the divided segments, or in more aggravated cases it may be necessary to turn down a flap of periosteum from the malleolus, and by stitching its apex to the outer side of the os calcis secure the tendon in place.

Rupture of Muscles and Tendons is by no means uncommon, resulting from violence of an unexpected nature. Most frequently the tendon gives way at its union with the muscular belly; less often

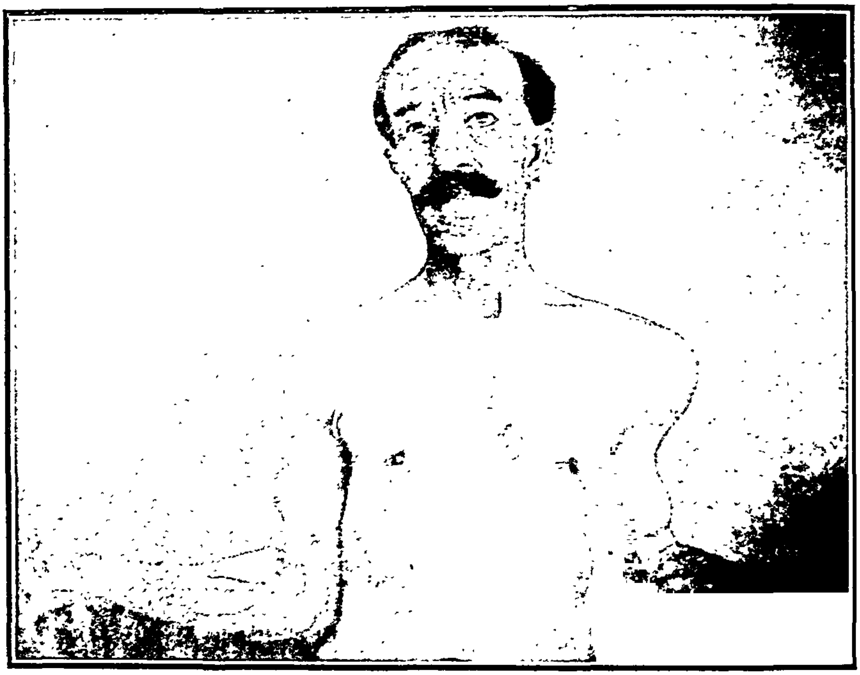


FIG. 205.—BILATERAL RUPTURE OF THE LONG HEAD OF BICEPS HUMERI.

the belly itself yields, whilst occasionally the tendon may snap, or the point of bone to which it is attached may be torn off.

Signs.—The patient at the moment of the accident experiences a sharp and severe pain, as if he had been struck with a whip; he may also feel or hear a snap. Loss of function follows, together with a certain amount of pain, swelling, and bruising, which are more evident if the muscular fibres have been torn across than if the tendon alone has been lacerated. On attempting to contract the affected muscle, the belly rises up as a soft, rounded, semi-fluctuating tumour (see Fig. 205), drawn towards the uninjured attachment, if the union between the tendon and belly has given way; whilst if the lesion has been through the muscular substance, the divided halves of the belly become similarly prominent, and a distinct gap or sulcus can be felt between them.

Repair is established by the formation of granulation, and finally

of cicatricial tissue. Where a muscle is involved and the ends are much separated, a long and weak bond of union forms; but when they are closely apposed, the cicatrix is short, and may be replaced subsequently by true muscular tissue. When a tendon has been divided or torn, the connecting medium is at first attached to the sheath, and if this adhesion persists, it may lead to pain and weakness. It is an interesting fact to note how rapidly this tissue becomes strong; a rabbit's tendon ten days after division requires a weight of 56 lbs. to break it (Paget).

Treatment.—It is essential to relax the parts fully so as to limit the separation of the divided ends and to maintain them in this position for two or three weeks. Any resulting stiffness is combated by passive movements and massage, whilst, if need be, adhesions are broken down under an anæsthetic. Tendons accidentally divided in open wounds should be sutured together by silk or catgut, careful antiseptic precautions being adopted to prevent suppuration along the tendon sheaths. Where there has been actual loss of substance in a tendon, one may be split longitudinally in such a way as to leave a thin flap attached peripherally, so that the free end can be turned down and united to the other segment (Fig. 206); or similar flaps may be provided from each end (Fig. 207); or it is possible to remedy the defect by grafting a portion of tendon from another region or person, or from an animal, between the two ends. Care must be exercised to prevent opposing muscles from dragging on and stretching the new bond of union, as thereby considerable functional disability may result.

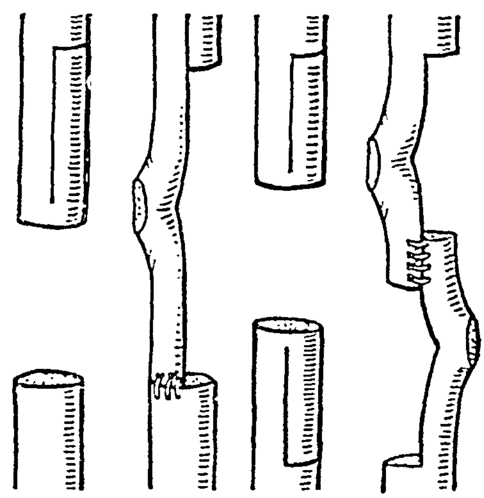


FIG. 206. FIG. 207.

METHOD OF UNION OF TENDON AFTER LOSS OF TISSUE.

In Fig. 206 the flap is taken from one end only; in Fig. 207 from both ends.

Muscular bellies which have been divided longitudinally or obliquely are easily united by sutures; but when the section is transverse, the stitches tend to cut out, unless the sheath can also be secured. In such a case it is advisable to encircle with a ligature a bundle of muscular fibres on either side of the incision, and then tie the two threads together. This must be done at several spots in the cross-section.

The *long tendon of the biceps* is not unfrequently torn from the muscular belly, which, on attempting to bend the arm, is drawn down towards the elbow, constituting a soft tumour, somewhat resembling a lipoma. No special treatment is needed beyond keeping the forearm flexed for a time. If the *tendo Achillis* is ruptured, union may be attained by keeping the knee bent and the heel raised, as by securing

a strap to the back of a slipper below, and to a dog-collar or suitable strap passed round the knee above. A better result, however, would follow an aseptic incision and suture. Similarly, if the *ligamentum patellæ* is torn across, suture through an open wound gives the best result. The *inner head of the gastrocnemius* is sometimes torn in wrenches or slips, as at lawn tennis, and the *plantaris* is similarly affected (see p. 458). The *adductor longus* may be lacerated in violent attempts to maintain a seat on horseback, and constitutes one form of rider's sprain; it is treated by rest and the application of a firm spica bandage, but in bad cases operation may be required.

The *long tendons of the fingers* are not unfrequently divided accidentally, and unless they are effectively sutured considerable impairment of function will result, the finger remaining in a position of flexion or hyper-extension, according to whether the extensors or flexors are involved. Operation to secure the divided ends should be undertaken at the earliest possible moment, but not until suitable aseptic conditions are present (see Fig. 208). Owing to the existence of a sheath the *flexor tendons* retract considerably, and a longitudinal incision in the middle line of the finger may be required to reach the proximal end. Its position can be indicated by the passage of a probe up the sheath, which is *incised only opposite the retracted end of the tendon.* A suture is introduced into the tendon and carried down the sheath, and thereby the retracted tendon is drawn again to the site where it was divided and secured to the distal end. By this manœuvre an extensive incision of the sheath is avoided, and adhesions are minimized. The finger must subsequently be kept on a splint, and active movements are not permitted for ten days.

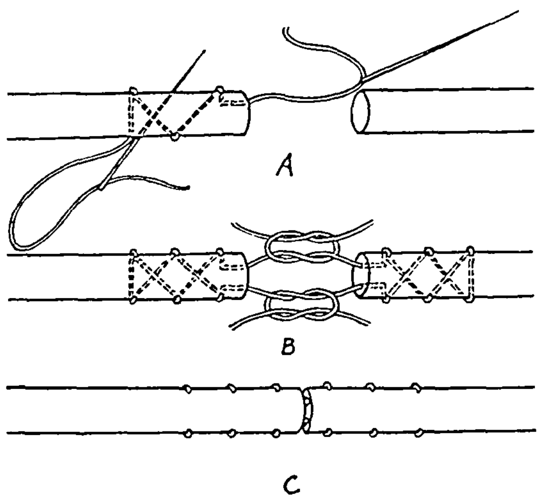


FIG. 208.—THE TECHNIQUE OF TENDON SUTURE.

The ends of the tendons are first trimmed. First one and then the other is transfixed with silk threaded into two needles. The ends of the tendon are brought into apposition, and the sutures tied. The knots lie between the ends of the tendon. A shows the method of suturing each end, and B shows diagrammatically how the knots lie. In C the appearance on completion of the operation is shown.

The *extensor tendons* have no synovial sheath on the fingers, and hence there is but little difficulty in securing them by suture, except when the attachment to the terminal phalanx is torn through, a not uncommon accident. The aponeurosis retracts and the thickened divided end can be felt opposite the centre of the second phalanx;

the terminal phalanx is bent and constitutes the condition known as a *mallet finger*. Fixation of the finger in a position of extension is useless in this condition, as approximation of the tendon to its point of attachment is not effected. Open operation is often unsatisfactory, since the tendon is torn completely away from the bone, and there is nothing to which to fix it. Good results are often obtained even at a comparatively late stage by putting up the finger with the metacarpo-phalangeal and first interphalangeal joints fully flexed, the second interphalangeal joint being extended—an uncomfortable position at first (see Fig. 209). The extensor aponeurosis is so attached that flexion of this type drags it downwards and relaxes its terminal segment so that satisfactory union is by this means much more likely to occur.

Contraction of tendons with a resulting deformity or disability will be produced by any condition which leads to destruction of muscle substance or partial loss of the tendon itself. It is likely to be associated with adhesions of the muscle to skin or fascia, or of the tendon to its sheath, and in military work may be complicated by nerve lesions. Occasionally it develops apart from open wounds, as in

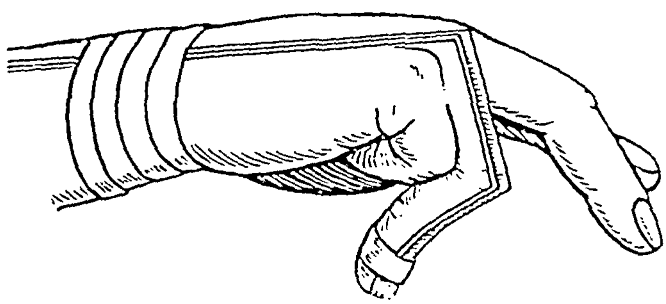


FIG. 209.—SPLINT FOR MALLET FINGER.

Volkmann's contracture and in certain nerve lesions. The possibility of the occurrence of this trouble should ever be kept in mind by the surgeon, so that preventive measures may be early instituted. When contraction has occurred, it is sometimes possible to overcome it by massage and ionization; but when a powerful muscle, such as the gastrocnemius, is involved, it is probably wiser to divide the tendo Achillis, and this should be effected, not by subcutaneous cross-section, but by open or subcutaneous division according to the Z-method (p. 473), so that the exact degree of lengthening necessary may be secured. In the case of less powerful muscles, as when the fingers are affected, treatment by splints, as described below, may be effective; but when the tendons are adherent to their sheath this is not very satisfactory, unless the adhesions can be broken down and the tendon thereby freed.

Diseases of Muscles.

Inflammation of Muscles (Myositis) may arise from a variety of circumstances, but the chief results are alike, whatever the cause, *viz.* a more or less painful infiltration of the muscle, with increased

discomfort on attempting movement. The part feels hard and rigid, and may be tender to the touch. If suppuration ensues, the ordinary signs of an abscess subsequently make themselves evident. A certain amount of contractile tissue is thereby destroyed, and the cicatricial changes induced will possibly lead to deformity.

Varieties.—1. **Simple Traumatic Myositis** results from contusion or laceration of the fibres, and is merely a plastic inflammation, with or without hæmorrhage, running on to resolution, with perhaps a little fibroid thickening of the part. It is liable in some cases to become chronic, the muscle substance becoming shortened and replaced by fibrous tissue (*M. fibrosa*), and this fibrosis may extend beyond the limits of the original lesion. The induration of the sterno-mastoid muscle met with in children is of this type, and may lead to torticollis.

A somewhat similar condition is known as Volkmann's **Ischæmic Contracture.** It is usually seen in children as a complication of fractures of the forearm or lower end of the humerus, which are treated by splints or firm bandages; but sometimes occurs due to great swelling of the arm following a fracture where no splints or bandages have been used. At the end of two or three weeks the flexor muscles become hard and contracted, and the fingers flexed and clawed, the wrist being hyper-extended. The deformity of the fingers disappears on flexion of the wrist, demonstrating thereby that no adhesions of tendons to sheaths are present. It is recognized from a nerve lesion by the absence of sensory or trophic phenomena. It is probably due to a necrobiosis of the muscular tissue from deprivation of blood owing to the pressure of a splint or bandage, and this is followed by a spreading myositis fibrosa.

Treatment is somewhat tedious and painful. It is best accomplished by the persistent use of splints applied so as gradually to stretch the contracted parts. Thus the hand is first put up with the wrist fully flexed and the fingers straight, though bent at the metacarpo-phalangeal articulation. By slow degrees the fingers are extended at this latter joint until the hand can be kept completely straight with a fully flexed wrist. The next stage consists in gradually extending the wrist with the hand straight, and it is remarkable how satisfactorily this treatment can restore the mobility of the hand and fingers, thereby avoiding the serious operative measures formerly adopted, such as lengthening of all the finger tendons or shortening of bones.

2. **Rheumatic Myositis,** or muscular rheumatism, is a condition often met with, especially in middle-aged men of rheumatic or gouty temperament who do not take enough exercise and live well. Septic teeth are also a frequent cause. The condition mainly involves the fibrous tissues, *e.g.* the fasciæ, aponeuroses, tendons and sheaths of muscles, or the ligamentous tissues of joints; hence the name **fibrositis** is often applied to it. Some forms of neuritis result from a similar affection of nerve sheaths (p. 393). Any part of the body may be involved, but in particular may be noted *lumbago*, in which the fascia lumborum is affected, the patient walking with a stiff back slightly

flexed; the pain often starts suddenly during some effort, and when present any unexpected movement elicits a sharp spasm. Rheumatic wry-neck is a similar condition, and may be induced by exposure to a draught. Pains in many joints—shoulders, knees, tendo Achillis, etc.—are of a similar nature, and sometimes are distinctly influenced by climatic conditions.

Treatment.—A good dose of calomel is in many cases desirable at the start, followed by suitable dietetic or medicinal remedies, and the teeth must be put into a good state of repair. Iodide of potassium is by some authorities looked on as always desirable. In the more active stages the part must be kept at rest, and dry or moist heat applied to relieve pain, whilst aspirin may be given for a similar purpose. Various methods of applying radiant or other forms of heat have been already alluded to (Chapter XI., p. 294). Vibro-massage is in many cases valuable. Hydrotherapy, when it can be utilized, is useful (p. 295), and the patient must be subsequently instructed to take more exercise and to live more simply.

3. **Acute Suppurative Myositis** is due to infection with pyogenic organisms, either from without, as after operation, or in penetrating injuries, etc.; or from within the body, as in pyæmia; or by extension from neighbouring suppurative foci, as from subperiosteal abscesses; it may also arise from a contusion or sprain by auto-infection. The local and general symptoms are severe, and pus is liable to spread widely within the sheath, or along fascial planes; great cicatricial deformity is likely to follow.

Treatment consists in providing efficient drainage to the part, the wound being dressed by one of the methods already indicated. This usually involves opening up the sheath freely, and the muscle may subsequently become adherent to the scar, and considerable deformity, disability and pain may result henceforth on using the part. After gunshot wounds, where muscles are frequently torn and infected, these troubles are constantly met with, and the functional value of arms and legs is much diminished thereby. In the treatment of these cases care must be exercised to adopt that position of limb which will leave the least contracture, as thereby deformities may be prevented. When the scars have formed, ionization with sodium chloride often has a valuable influence in making them more supple, and massage assists in restoring utility to the part.

4. **Chronic Tuberculous Myositis,** with the formation of a chronic abscess, is not an uncommon secondary consequence of a similar affection of neighbouring bones or joints, *e.g.* a psoas abscess.

5. **Syphilitic Disease** is usually met with in the tertiary period, and takes the form either of a diffuse sclerosis or of a localized gumma. Any muscle may be affected, but perhaps the tongue and sterno-mastoid are those most frequently involved. Care is needed in order to diagnose these conditions from tumours; but the presence of a syphilitic history and a positive Wassermann reaction, the slow growth, the hardness with subsequent central softening, and the rapid disappearance after the administration of iodide of potassium, should suffice to determine their nature.

Occasionally gummata appear in muscles in the shape of small, hard and shotty nodules, usually arranged more or less longitudinally, which are painless and apparently attached to the fascial sheath. They react readily to iodide of potassium.

6. **Parasitic Myositis,** arising from the presence either of the *Trichina spiralis* or of hydatids, need not be described here.

7. **Myositis Ossificans** is a rare disease, usually seen in young males, in which various muscles, especially those of the back, are transformed into bony plates or rods, so as to lead to extensive ankylosis. The process seems to be one of ossification of the connective tissue associated with atrophy of the muscular fibres, and is sometimes extremely painful. In a boy under observation the arms were immobilized by ossification of the latissimus dorsi muscles on either side, whilst the pectoralis major was also ossified on the right side (Fig. 210). The erector spinæ was involved, the back being rigid, and the right trapezius was undergoing the same change. This disease is often associated with a congenital deficiency of the proximal phalanx of the great-toes. No treatment has proved of any value.

FIG. 210.—SKIAGRAM OF A CASE OF MYOSITIS OSSIFICANS OF THE ARM MUSCLES.

Quite distinct in nature is the *Traumatic M. Ossificans*, of which two varieties are described: (i.) The new formation results from persistent and repeated irritation of muscles or tendons, and usually starts from the periosteal attachment. The 'rider's bone' developed in the tendon of the adductor longus is of this description. (ii.) Less commonly the affection follows a severe injury to a muscle associated with a fracture or dislocation, whereby the periosteum is torn and bone-cells (osteoblasts) are set free. A certain amount of hæmorrhage follows, and in the reparative tissue developed in the muscle the bone-cells find a suitable nidus for development, and the new tissue formed undergoes ossification. In about three or four weeks the presence of bone can be recognized by palpation as a deep indurated mass, usually movable on the bone and across the fibres of the muscle involved; at a later date the new bone can be seen by radiography (Fig. 211). Painful limitation of movement may ensue, but if possible the condition is left alone, unless the disability is great, and then removal must be undertaken. The muscles in which this change has been most commonly observed are the quadriceps femoris and the brachialis anticus.

Tumours of Muscles are not very common. Primary growths consist of angioma, lipoma, fibroma, chondroma, myxoma, or sarcoma,

and of these the majority start in the fibrous sheaths of the inter-fibrillar connective tissue. Secondary deposits of both carcinoma and sarcoma also occur. **Treatment** is conducted on ordinary surgical principles. If sarcomatous, the whole thickness of the muscles should, when possible, be excised for some distance from the growth, since the lymphatics run in the direction of the fibres, but the sheath forms a limit not early overstepped. Amputation of the limb may, however, be required.

FIG. 211.—MYOSITIS OSSIFICANS OF THE BRACHIALIS ANTICUS.

Skiagram taken one month after injury. Note the clear zone between the shadow and the shaft of the humerus. The commonest sites are the brachialis anticus and the quadriceps.

Diseases of Sheaths of Tendons.

1. **Acute Simple Teno-Synovitis** often follows sprains and strains, and is most commonly seen in connection with the extensor muscles of the thumb. A puffy swelling in the course of the tendon is produced, painful on movement and perhaps tender to the touch, giving a characteristic fine crepitus whenever the parts are moved.

Treatment.—Immobilize the limb for a few days, and apply fomentations. As soon as the more acute symptoms have disappeared, massage is employed to hasten the absorption of the fluid; whilst active and passive movements are undertaken to prevent the formation of adhesions.

2. **Acute Suppurative Teno-Synovitis** may result from a punctured wound of the synovial sheath, or the inflammation may spread to it

from neighbouring tissues. The thecal variety of whitlow (p. 246) is of this nature. Suppuration may extend both up and down the sheath, and unless promptly treated by incision, the tendon will slough, or may contract extensive adhesions to neighbouring parts; in either case considerable impairment of function is likely to follow. When the tendon survives, active and passive movements must be started very early if the formation of serious adhesions is to be prevented. The suppuration may affect neighbouring articulations, leading to their disorganization, especially in the case of the tendon sheaths around the wrist-joint.

3. **Chronic Simple Teno-Synovitis** is a common affection, characterized by a passive effusion into the tendon sheath of glairy synovia, somewhat resembling uncooked white of egg. An elastic fluctuating swelling forms in the course of a tendon, usually associated with creaking. In the more limited varieties it constitutes one form of ganglion. There is no pain or tenderness, but the affected part feels weak. **Treatment** consists in counter-irritation and pressure, as by Scott's dressing; failing this, the part may be freely incised, the synovia removed, and, if need be, the cavity washed out. In the more localized forms it may suffice to puncture the cyst-like swelling and squeeze out the contents, pressure being subsequently applied.

4. **Stenosing Teno-Vaginitis** is found in relation to the short extensors of the thumb and often more commonly in women. Although there is no history of trauma, yet repeated small unrecognized injuries may play their part in the causation of this condition, which has a very insidious onset. Pain is the reason why the patient seeks advice; the pain is caused by active abduction of the thumb, and usually a visible swelling is present over the styloid process of the radius (Fig. 212). The swelling is ovoid in shape, and is tender on pressure. Pain can be elicited by abducting the thumb, and is caused by obstruction of the free movements of the tendons of abductor pollicis longus and extensor pollicis brevis as they pass beneath the dorsal carpal ligament.

Operation is the only **Treatment** which is of any avail, and is nearly always successful. The actual operation can be performed under local anæsthesia; an incision is made through the skin over the swelling and the superficial fibrous sheath of the tendons excised (Fig. 212). The tendons can be made to move quite easily after this, and the skin is then sutured.

5. **Chronic Tuberculous Teno-Synovitis** is of two types. In one the sheath is lined by œdematous granulation tissue of some thickness, containing tuberculous foci, giving rise to a soft elastic swelling along the course of a tendon, which increases slowly in size, and is but slightly painful or tender. Suppuration may follow, and subjacent bones or joints be involved.

The other form of tuberculous disease consists in a passive effusion into the synovial space, the lining membrane of which becomes thickened by the deposit thereon of fibrinous material. This is often detached, and by the movements of the part the loose fragments of fibrin are moulded into various shapes. In tendon sheaths they are

often elongated, and constitute the so-called *melon-seed bodies*; but when they occur in joints, they remain somewhat flattened, whilst in bursæ they approximate more to the spherical. On examination, they are found to be structureless, though sometimes laminated. When numerous, they give rise to a curious and characteristic form of crepitus. That they are of a tuberculous nature can be demonstrated by inoculation experiments; the bacilli contained therein are not, however, in a very active state, and the prognosis of this type is more favourable than that of the former.

The **Treatment** of both these forms consists in the local application of the principles described at p. 175. The patient is put under the best climatic and general conditions that are possible, and the affected part is immobilized. The application of Scott's dressing may be desirable, and passive hyperæmia by means of an elastic bandage should be practised daily. Suppuration, if it occurs, is dealt with

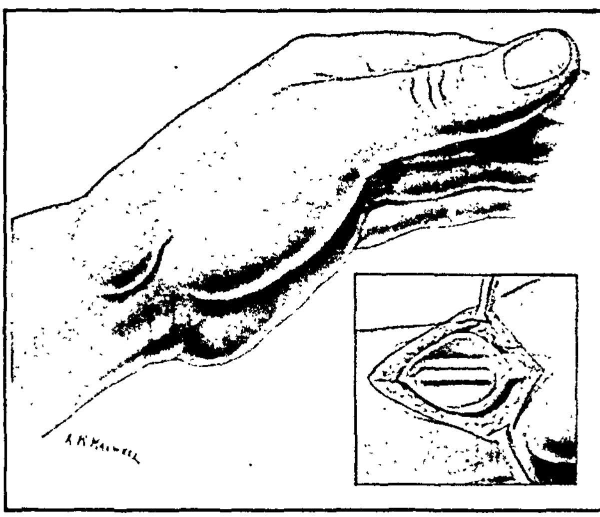


FIG. 212.—OPERATION FOR STENOSING TENO-SYNOVITIS.

by tapping; but if the effusion in the latter variety becomes excessive, it may be wise to incise the sheath and wash out the melon-seed bodies together with the fluid; but under no circumstances should extensive operations be undertaken for the removal of the tuberculous tissue.

A **Ganglion** is the term given to a localized cyst-like swelling forming in connection with a tendon sheath or joint. It is most commonly met with at the back of the wrist, arising from the tendons of the radial extensors of the carpus, and those of the thumb or index-finger, but it sometimes occurs on the front of the wrist or in the foot (Fig. 213). It varies in size considerably, and contains a clear, transparent, gelatinous or colloid substance. A rounded, firm, elastic swelling is produced, usually somewhat movable, and neither painful nor tender at first, although some painful weakness of the part may be experienced as it increases in size. It may result from a chronic localized teno-synovitis, or from a hernial protrusion of the synovial membrane

through an opening in the sheath; certainly some few arise in connection with subjacent articulations, in the same way as a Baker's cyst. Another theory is that ganglia arise as a mucoid degeneration in fibrous tissue adjacent to a tendon sheath or joint. Little difficulty arises in the diagnosis, although, when situated deeply and closely attached to a bone, they have been mistaken for exostoses; their connection with a tendon sheath is indicated by the possibility of moving them at right angles to the direction of the tendon, but not up and down.

Treatment.—A ganglion may often be ruptured by manipulation and pressure with the thumbs. Failing this, a rapid cure is usually obtained by an aseptic puncture of the cavity, and the subsequent application of firm pressure. In some cases it may be advisable to lay the part open and remove the cyst wall as completely as possible; such treatment requires absolute asepsis, since, if infection occurs, most serious consequences may ensue.

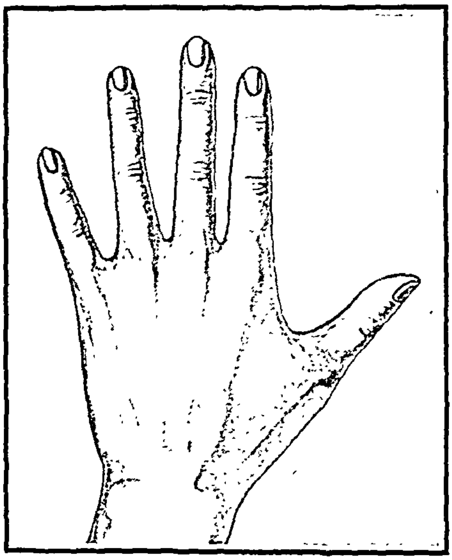


FIG. 213.—GANGLION OF EXTENSOR TENDON OF THE HAND.

A **Compound Palmar Ganglion** consists in a tuberculous affection of the common synovial membrane surrounding the flexor tendons of the wrist, the cavity being distended in the early stage with a glairy fluid, usually containing many melon-seed bodies, and perhaps later on with pus. In the early stages all that is noted is a fulness about the front of the wrist and palm, the normal hollow being obliterated. Later on a more definite swelling is observed, and this is found to extend into the thenar eminence, due to the involvement of the tendon sheath of the flexor longus pollicis. The condition is painless at first, and there is but little interference with the mobility of the tendons; but in the later stages the tendons may become matted together, and the movements of the fingers hampered; or if the disease ends in suppuration, the pain and disability become more marked. In all stages fluctuation can usually be detected above and below the annular ligament, being transmitted beneath it.

Treatment is of the usual anti-tuberculous type. The patient is sent to a sanatorium or placed in conditions approximating to it. The hand is kept at rest, but one full range of movements should be allowed daily so as to guard against unnecessary adhesions. Passive congestion by the use of a Martin's bandage is practised each day for an hour or two. If the effusion shows no signs of absorption after a sufficient interval, it may be removed by tapping and washing out,

but there must be no handling or displacement of the tendons. Suppuration is dealt with by tapping, or if the skin becomes thin and undermined, by free incision and packing with gauze soaked in iodoform and glycerine. Operative treatment may be undertaken, the whole palmar bursa being removed by dissection.

Myeloma may arise in connection with the tendon sheaths of the fingers. A soft rounded swelling is seen on the dorsal or lateral surface of the finger (Fig. 214). Excision of these small tumours is quite easy,

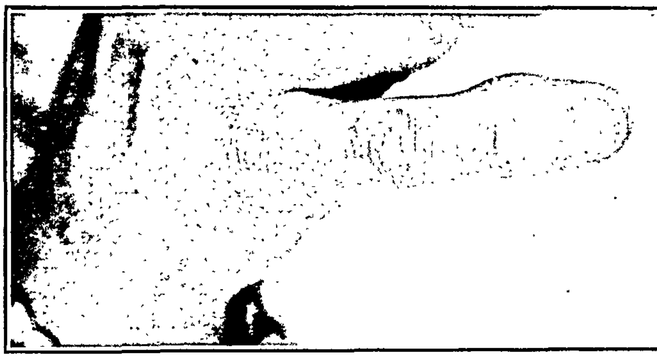


FIG. 214.—MYELOMA OF EXTENSOR TENDON OF THE LITTLE FINGER.

and recurrence does not take place. On section the tumour mass is of an orange-yellow consistence, and microscopically giant cells are in evidence, but not as a rule so numerous as in the myelomata which are found in bones.

Operations on Tendons.

1. By **Tenotomy** is meant the division of a tendon through an open or subcutaneous wound with the object either of remedying some deformity, such as talipes or torticollis, or of assisting in the reduction of some displacement, as in setting a fracture. It is accomplished in two ways, *viz.* by subcutaneous or open incision. The **subcutaneous** method is employed where there is little likelihood of injuring important structures. The strictest attention to asepsis is essential, since the character of the wound, *viz.* a puncture, and the entire absence of drainage, are most favourable to the development of organisms, if entrance is once given to them. Moreover, the synovial tendon sheath is often, though undesignedly, wounded, and infection spreads rapidly along such a structure, and gives rise to serious consequences. The operation consists in inserting a sharp-pointed tenotome through the skin down to the tendon. This is then withdrawn, and a blunt-pointed knife passed along the track thus made, either superficial to or beneath the tendon. The cutting edge is turned towards it, and the tendon divided by a sawing or rocking movement, whilst the structure is put on the stretch. It is undesirable to operate through the synovial sheath, since even if the wound remains aseptic the tendon often retracts more than is desirable, and in healing gains adhesions to the sheath, which considerably limit the subsequent freedom of movement of the part. Opinions vary as to whether it

is better to pass the knife above or below the tendon; in the former method there is no likelihood of making an unduly large wound in the skin, and there is less risk of dividing the *lax* subjacent structures if the knife is turned towards them. On the other hand, if the knife is at once passed beneath the tendon, and any subjacent structures are by mistake included, their division is a matter of certainty. Where, however, there is any risk of dividing important structures, such as the external popliteal nerve in tenotomy of the biceps cruris, it is wiser to adopt the **open method.** The malposition is at once corrected, and the part immobilized at the time, or in the course of forty-eight hours, in plaster of Paris. Passive movements may usually commence at the end of twelve to fourteen days, and gradually be increased in vigour, until active movements are allowed.

Tenotomy of the Tendo Achillis.—The foot is placed on its outer side, and the tendon relaxed by pointing the toes downwards. The tenotome is introduced at the inner margin of the tendon, about 1 inch above its insertion (Fig. 143, F, p. 353), either superficial to or beneath it, and it is readily divided when the foot is dorsiflexed. If the surgeon cuts towards the skin, he must not divide the last few fibres too rapidly, otherwise a considerable external wound may be inflicted by the suddenly liberated knife.

The *Tibialis Anticus* is usually divided about 1 inch above its insertion, as it crosses the scaphoid (Fig. 145, p. 354), and is free from a synovial sheath. It is first relaxed so as to allow of the introduction from the outer side of the sharp-pointed tenotome beneath it; this is replaced by a blunt-ended instrument, and the section is accomplished when the foot is abducted.

The *Tibialis Posticus* is divided, together with the flexor longus digitorum, just above the inner malleolus, about a finger's breadth from the tip of that process in an infant, and about 1½ inches from it in an adult (Fig. 143, E, p. 353). The knife is inserted between the tibia and the tendon, and if correctly placed, remains fixed without the support of the hand, being grasped between the tendon and the bone. The blunt-ended tenotome is then introduced with its edge towards the tendon, the latter structure being divided when the foot is dorsi-flexed.

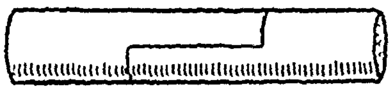
The *Peronei* tendons are divided just above the base of the outer malleolus, at a spot where the synovial sheath is usually absent (Fig. 144, D, p. 353). The tenotome is inserted close to the fibula, between the tendons and the bone.

The *Biceps Cruris* tendon is best divided by an open operation, so as to avoid the external popliteal nerve, which has often been wounded in the subcutaneous method. An incision is made in the direction of the tendon just above its insertion into the fibula. It is then lifted upon an aneurism needle and divided; muscular fibres will probably be found quite close to its lower end.

The *Semi-membranosus* and the *Semi-tendinosus* tendons are dealt with just above the knee-joint, and the subcutaneous operation may be conveniently adopted when they are prominent and tense.

For division of the *Sterno-mastoid*, see p. 484.

2. **Lengthening a Tendon** is sometimes required in order to overcome the deformity which results from loss of substance or contraction, where simple tenotomy does not seem desirable. The most efficient method is the so-called Z-operation (Fig. 215). The tendon is split longitudinally into two halves, which are separated one from the other by cross-cuts made on opposite sides, one at each end. The two flaps are then drawn apart for a distance corresponding to the increase in length required, and sutured together; the resulting bond of union will be as represented in Fig. 216. This operation is usually performed through an open wound, but for the tendo Achillis it is quite easy to undertake it as a subcutaneous procedure. The tendon is half-divided on opposite sides through two punctures 1½ inches apart, and then by forcible dorsiflexion 'the two halves of the tendon are made to slide on one another until the required lengthening is obtained' (Robert Jones).



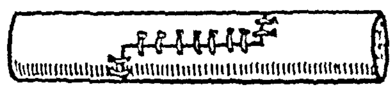


FIG. 215. FIG. 216. FIG. 217.

Z-OPERATION FOR LENGTHENING OR SHORTENING OF TENDONS.

In Fig. 215 the method of dividing the tendon is shown. In Fig. 216 the flaps are slipped downwards, one on the other, so as to lengthen the tendon. In Fig. 217 equal portions have been cut away from each half and the remainders sutured, so as to shorten it.

3. **Shortening a Tendon** is undertaken in some forms of paralytic talipes. The Z-method may also be employed here, the two halves, after they have been separated, being shortened to the required amount, and then stitched together (Fig. 217). This operation gives a more solid bond of union than when a transverse or an oblique section is removed; in such the sutures are more likely to cut out.

4. **Tenoplasty** is the term applied to any plastic operation on tendons with a view (1) to transfer the action of a healthy and strong muscle to the tendons of a weakened or paralyzed group, so as to limit deformity or disability; or (2) to displace the line of action of a muscle so as to counteract or obviate deformity; or (3) to utilize a paralyzed tendon as an accessory ligament. Clearly, this operation finds its greatest use in paralytic affections. It is essential to study carefully the peculiar features of each case, especially as to the electrical reaction and power of all the muscles involved, and the relative importance of each possible movement. Thus, in the foot, plantar flexion is of more value than dorsiflexion, and the latter is more useful than either

adduction or abduction, whilst of the two last-mentioned movements adduction is more important than abduction. Hence, although it would be mechanically correct to transplant a healthy abductor, such as the peroneus longus, into a paralyzed plantar flexor, such as the tendo Achillis, so as to improve plantar flexion at the expense of abduction, it would be unwise to reverse the proceeding. It is desirable that, whenever possible, the reinforcing tendon should be derived from a synergic and not from an opposing group.

Various methods of tenoplasty are available: (1) *Tendon Implantation* consists in suturing the whole or part of the proximal end of the tendon of a healthy muscle to the distal end of the divided tendon of a paralyzed muscle, and for choice the latter should be divided as near its insertion as possible. The actual method of union of the

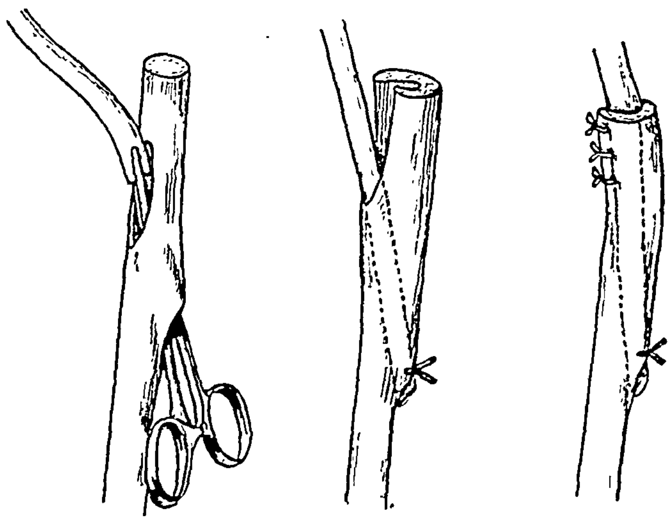


FIG. 218.—TENDON IMPLANTATION.

A hole is tunnelled obliquely through the healthy tendon, and the paralyzed tendon is drawn through this and fixed by sutures. At the free end the receiving tendon is split longitudinally and wrapped round the paralyzed tendon, so as to improve the fixation.

tendons varies with circumstances, but the best results have been obtained by tunnelling the healthy tendon and drawing the divided end of the paralyzed tendon through it, and uniting them thus by sutures (Fig. 218). Direct end-to-end suture of two tendons is less satisfactory. Occasionally merely a slip from the stronger tendon is employed, which is attached to the weaker one so as to fortify the latter without destroying the power of either. (2) By *Tendon Transplantation* is meant the total detachment of a tendon from its point of insertion, with or without the periosteum or bone to which it is attached, and its transference and fixation to the point of insertion of the tendon of a paralyzed muscle, or to some spot where it can act more advantageously. It is fixed either by sutures to the periosteum, or by drilling a hole through the bone and threading the tendon through it. (3) A somewhat similar procedure, which may be termed *Tendon*

Fixation, is sometimes employed in order to steady flail-like paralyzed parts. Thus in hopeless foot-drop of paralytic origin it may be desirable to divide the extensor or peronei tendons and attach their distal segments by suitable methods to the tibia to act as accessory ligaments.

The greatest care must be taken with the technique of these operations, so as to ensure complete asepsis and perfect hæmostasis. Tendon sheaths must be closed by the finest catgut or silk sutures. Deformities should be corrected before the tendons are united, so as to ensure accurate length of the new structure. The after-treatment is in the first place directed to the avoidance of undue tension on the bond of union for fear that it may stretch. The parts should be kept in an over-corrected position for six weeks by splints or plaster of Paris. Subsequently a supporting instrument must be worn for six months, and the affected muscles are treated by massage, electricity, and educative exercises.

Diseases of Bursæ.

Bursæ exist as normal structures in many parts of the body exposed to pressure, their object being to diminish friction and permit of a gliding movement. Similar cavities, known as abnormal or **Adventitious Bursæ,** are developed in regions where exceptional pressure is brought to bear on some prominent structure; they consist of a fibrous wall lined by a serous membrane, contain a small quantity of serum, and are formed either by dilatation of lymphatic spaces, or as a result of a localized effusion into the tissues. Examples of this are met with in men following special occupations, *e.g.* over the vertebra prominens of Covent Garden porters, and then known as a 'hummy'; Billingsgate fish-carriers occasionally have bursæ under the centre of the scalp; and deal-runners often present one on the upper part of the shoulder. They occur over bony prominences arising from malformation or displacement, *e.g.* over the cuboid in talipes equino-varus, and over exostoses; whilst the false joint or pseudarthrosis which occurs in unreduced dislocations or ununited fractures is of a similar nature.

Wounds of bursæ may be caused by penetrating injuries, or sometimes by the skin over them splitting, as, *e.g.*, in a fall on the point of the olecranon. The escape of bursal fluid which results often prevents healing, and then it will be necessary either to excise the bursa, or to open it freely, so that it can be packed and allowed to heal from the bottom.

Subcutaneous injuries are followed by hæmorrhage, constituting a hæmatoma, which may suppurate or become absorbed; in the latter case adhesions will often occur, and even polypoid fringes from the organization of the blood-clot. Treatment consists in keeping the part at rest, unless suppuration is threatening, and then an incision must be made. It is always well to make certain that no fracture is present beneath a hæmatoma of the olecranon or patellar bursæ.

The following are the morbid conditions which arise in adventitious as well as normal bursæ:

1. **Acute Simple Bursitis** results from moderate injury or prolonged irritation, especially in gouty or rheumatic individuals. The part becomes swollen, painful, and tender, and if superficial the skin over it may be hyperæmic. Effusion into the cavity quickly occurs, and is sometimes mixed with blood. Lymph is deposited on the serous surface, and in many cases results in the formation of adhesions, and possibly obliteration of the cavity. **Treatment** consists in keeping the part at rest, and applying fomentations. If the effusion persists, aspiration, or removal with trocar and cannula under strict asepsis, may be employed, or even the whole cavity excised.

2. **Acute Suppurative Bursitis** arises from infection occurring either from without or within; it not uncommonly follows a subcutaneous injury of a chronically inflamed bursa, leading to its distension with blood. The pus, formed at first within the bursa, may travel directly to the surface, or, bursting through the capsule, is diffused through the tissues. Where this occurs, the characteristic features suggesting a bursal origin of the abscess may be masked. Thus, in suppuration of the bursa patellæ, the pus often finds its way to the lateral aspects of the limb, allowing the patella to be distinctly felt through the skin; the case might then be mistaken for suppuration within the knee-joint, but is easily distinguished by the absence of the more acute arthritic symptoms. Implication of subjacent bones and joints sometimes occurs; thus, the patella or olecranon may become carious, or necrose. **Treatment** resolves itself into an early free incision, and drainage.

3. **Chronic Bursitis with Effusion** is, perhaps, the most common pathological condition met with in bursæ. The cavity becomes distended with a serous effusion of varying amount, giving rise to a *fluctuating* swelling. The walls differ in thickness according to circumstances; if the condition is one of long standing with frequent recurrences, the bursal wall is usually reticulated and dense, and adhesions, papilliform processes, or fibrous cords are often produced. Subacute exacerbations are frequent. **Treatment** consists in rest and counter-irritation, as by blistering or iodine paint, and if this fails, the bursa should be dissected out. When the bursa communicates with a joint, such as that under the semi-membranosus tendon, the neck must be isolated, and its communication with the joint shut off by ligature.

4. **Chronic Tuberculous Bursitis** is either characterized by effusion and the presence of loose fibrinous bodies (melon-seeds), or the lining membrane is transformed into granulation tissue of a tuberculous type, perhaps leading to the formation of a chronic abscess. Either condition may be secondary to a tuberculous arthritis, or may give rise to it, when the bursa communicates with a joint. If total removal is impracticable, **Treatment** is similar to that for chronic tuberculous teno-synovitis (p. 469).

5. **Syphilitic Changes** may also occur in bursæ in the shape either of a symmetrical bursitis with effusion in the early stages, or later on as a gummatous perisynovial development. In this variety, often termed *chronic fibroid bursitis*, the walls of the bursa are much

thickened, constituting a hard fibroid tumour, in the centre of which is a small cavity. If the gummatous material breaks down, deep openings may develop into the swelling. Anti-syphilitic treatment may assist in healing the sores, but total excision is necessary in order to cure the case.

6. Occasionally **Gouty Deposits** are observed in the walls of bursæ, constituting tophi, the irritation of which may predispose to abscess formation, pus mixed with urate of soda crystals being discharged. The olecranon bursa is that most frequently affected in this way.

Special Bursæ.

The *bursa patellæ* (Fig. 219), which lies over the lower half of the bone and not over its centre, is very liable, from its exposed situation, to injury or any of the above-mentioned varieties of bursitis. In its

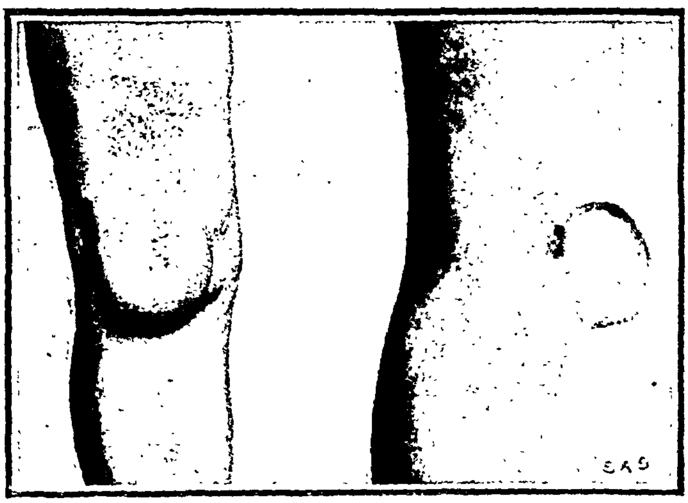


FIG. 219.—ENLARGED BURSA PATELLÆ.

simplest form it constitutes the condition known as 'housemaid's knee,' and is due to kneeling. Caries of the patella may follow acute suppuration, and the more chronic varieties may lead to osteoplastic periostitis. The knee-joint itself usually escapes.

The *bursa beneath the ligamentum patellæ*, between it and the head of the tibia, when distended with fluid, gives rise to a fluctuating swelling felt on either side of the tendon, more especially when the limb is extended; when the leg is flexed, the swelling diminishes. Chronic enlargement of this bursa may push the ligamenta alaria backward into the joint, so that they are nipped between the bones whenever the patient attempts to stand with the leg extended; the pain thereby induced is somewhat similar to that caused by a displaced semilunar cartilage, or by a loose foreign body in the joint. The presence of the enlarged bursa, together with the inability to stand with a straight leg, should suffice to make the diagnosis clear.

The *bursæ in the popliteal space* are often enlarged, especially that

between the inner head of the gastrocnemius and the semi-membranosus (Fig. 220), leading to a rounded fluctuating swelling, sharply limited on its outer aspect, and more fixed and less defined towards the inner. The sensation imparted to the fingers varies according to the position of the limb, the swelling being *tense in extension and flaccid in flexion*, as occurs in most of these periarticular bursæ. Owing to the proximity of the popliteal vessels pulsation is occasionally detected, but is not expansile in character. Enlargement of this bursa

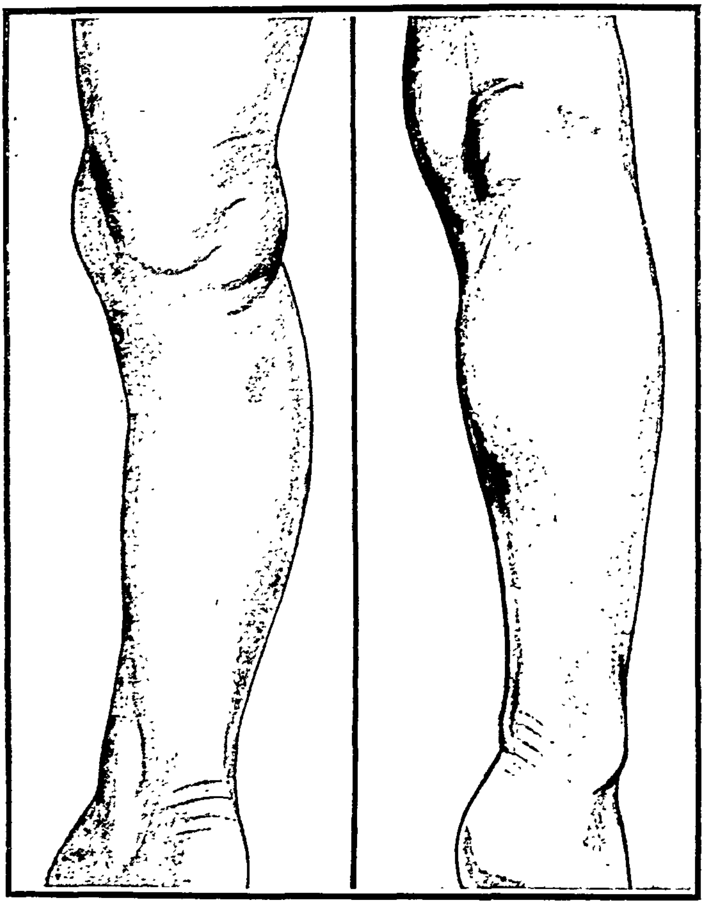


FIG. 220.—ENLARGED SEMI-MEMBRANOSUS BURSA IN A BOY VIEWED FROM TWO ASPECTS.

is often secondary to an articular lesion, especially tuberculous disease or osteo-arthritis, and before undertaking treatment the condition of the joint should be ascertained. If the joint is healthy, the bursa may be removed by dissection, the pedicle being closed by ligature or suture.

The *bursa beneath the insertion of the semi-tendinosus and gracilis* is sometimes inflamed, and is very liable to cause osteoplastic periostitis of the subjacent inner surface of the tibia.

The *bursa beneath the tendo Achillis*, if enlarged, presents a fluctu-

ating swelling on either side of that structure, somewhat simulating disease of the ankle-joint, but necessarily limited to the posterior aspect of the joint. Primary tuberculous disease is sometimes present.

Distension of the *bursa beneath the psoas tendon* gives rise to a fluid swelling which usually projects anteriorly, presenting either on the outer or inner side of Scarpa's triangle. If painful, it necessitates flexion of the thigh, and thus leads to symptoms resembling those of hip-joint disease or of a psoas abscess. It must not be forgotten that this bursa often communicates with the joint.

The *gluteal* bursa, situated between the insertion of the gluteus maximus and the great trochanter, is not uncommonly the seat of tuberculous disease. It presents as a rounded swelling, obliterating the hollow behind the trochanter, and in its more acute manifestations may be accompanied by abduction and eversion of the limb, in order to relax as far as possible the gluteus. It may thereby somewhat resemble the earlier stages of hip disease, but is recognized by the absence of flexion, and by the fact that passive movements, including even the so-called test-movement for hip disease, can be undertaken with but little or no pain. Should suppuration occur, the pus may burrow widely beneath the gluteus. Treatment consists of complete excision, if possible, or incision with scraping and disinfecting the interior, and allowing it to heal from the bottom. Necessarily part of the insertion of the gluteus maximus will require division, and must be subsequently sutured.

The *bursa over the tuber ischii*, if inflamed, gives rise to the condition known as 'weaver's bottom'; it causes great discomfort in sitting, and is often solid and symmetrical. If troublesome, it should be removed.

Enlargement of the *bursa over the olecranon* constitutes the condition known as 'miner's elbow'; suppuration within it is not uncommon, leading to necrosis of the underlying bone; the elbow-joint is but rarely affected.

The large multilocular *subdeltoid bursa* is occasionally enlarged, and may be the site of a simple chronic effusion or of a tuberculous hydrops with melon-seed bodies. It leads to prominence of the deltoid and expansion of the shoulder, which is liable to be mistaken for an effusion into the shoulder-joint, but is recognized without much difficulty, as the swelling is usually greater, and there is no axillary intumescence. Treatment consists in tapping and irrigation, or injection of iodine, or, failing that, drainage. As a final resource the deltoid can be partly detached and turned down, and the bursa dissected away.

CHAPTER XIX.

DEFORMITIES—ORTHOPÆDIC SURGERY.

ORTHOPÆDIC Surgery has for its aim the maintenance of the normal mechanical functions of the trunk and limbs, as well as the correction of such departures from the normal as constitute deformities.

Deformities may arise from many diverse causes, and it is essential to study them carefully from this point of view if correct treatment is to be secured. They may be *congenital* in origin, and thus may be inherited or the result of some lesion or defect in the health of the expectant mother; *traumatism* is the cause of not a few, either directly or as the result of inflammatory phenomena caused thereby. *Irregular growth* of various parts of the body from malposition or injudicious function is also an important ætiological element; especially is this the case in certain bony deformities, since the development of osseous tissue is so largely dependent on the strain to which the bone is exposed, and if this strain falls along abnormal lines, then abnormal growth will be Nature's response, and deformity will result. Muscles and ligaments must, of course, accommodate themselves to the bony skeleton. Quite a number of deformities are due to *static* causes of this character. Finally, the *nervous* system plays a certain part in many cases and in many different ways.

From the anatomical standpoint, deformities may be classed as due to the following causes:

1. Contractions of the skin, subcutaneous tissues and fasciæ, as in cases of burn, cellulitis, etc. Scar tissue does not grow as quickly as other tissues, and therefore deformity may sometimes become exaggerated as a child grows.

2. Unbalanced action of opposing groups of muscles from whatever causes this is due—*e.g.*:

(*a*) Simple want of tone from disuse, paralysis, etc., resulting in elongation of muscles or tendons.

(*b*) Persistent spasm, either clonic or tonic.

(*c*) Intrinsic contractions of the muscle substance, or adhesions of muscles or tendons to surrounding parts.

3. **Ligamentous** changes may lead to articular deformities.

(*a*) Simple relaxation from persistent malposition or chronic distension may lead to instability or even displacement of joints.

(*b*) Contraction of ligaments of static or inflammatory origin may result in more or less limitation of movement.

(*c*) Actual ossification of ligaments sometimes occurs, and causes ankylosis.

4. **Osseous** causes are most variable in type, *e.g.*:

(*a*) Irregularities of growth in the direction either of excess or effect may be congenital, static, or inflammatory in origin.

(*b*) Non-union or the vicious union of fractures is a fertile source of orthopædic trouble.

5. **Articular** causes are of manifold varieties, resulting from malposition, congenital or acquired, inflammatory troubles or traumatism.

6. **Nervous lesions** may cause paralysis or spasm, and many types of deformity result therefrom.

A careful study of the above ætiological summary will make it abundantly obvious to anyone that a large percentage of all deformities is preventable, and attention has already been drawn more than once in this work to the value of the old proverb that 'prevention is better than cure.' A very large proportion of the work undertaken at the orthopædic centres in connection with the late war could easily have been prevented with a little foresight and more care on the part of attending medical officers.

A few general principles which govern orthopædic treatment may be mentioned here, but it is obvious that space does not permit more than a brief note.

1. **Persistent malposition results in permanent structural changes.** Thus accommodative shortening of ligaments, muscles, etc., will take place on the flexor side of a bent knee or wrist, whilst the structures on the extensor side will be stretched and in time from want of use will become atrophied. Should the parts be subsequently replaced, the stretched extensors still remain weak and functionless, as the contraction of the muscles cannot 'take up the slack' in the tendons. The importance of this has been emphasized in connection with nerve lesions, whether traumatic or due to poliomyelitis. Joints conform to this rule, and ligamentous changes may even run on to ossification if there is much pressure or tension, the deformity thus becoming hopelessly fixed.

2. **Growth of bone** is governed by the amount and direction of the forces and strain to which it is exposed. Normal strain in a normal position means normal growth. Abnormal strain even in a good position may result in deformity, especially if the general condition is poor; but if time be allowed for repair and improvement of the general health, the bony tissue may recover and become consolidated in the abnormal position, and the resulting bony tissue may be more solid and stronger than ever. Thus in rickets the long bones often become bent, but strengthening buttresses develop in the concavity of the bent bones, and the final issue when repair has occurred is an abnormally solid bone. Similarly the kyphotic spine of 'hunch-backs' may become preternaturally powerful and solid.

On the other hand, want of use and loss of function are very quickly represented in bony tissue by atrophic changes.

If by operation or otherwise deformed parts can be placed in a normal position once again so that normal strains are brought to bear upon them, a return to a normal structure may be expected. This latter desideratum is, however, also governed by the age of the patient

and the length of time that the deformity has lasted. In young people all growth tends towards the normal, but in older people the tissues do not respond so readily.

3. **Exercises** in which a displaced part can be brought either gradually or from the first into the normal position will develop the muscles, etc., which have become stretched, functionless, or atrophic, and as the normal position is more easily and effectively maintained, the structures which surround it return more exactly to the normal. The use of remedial exercises and re-educational methods is based on this fact. It must always be remembered, however, that it is useless to develop only one group of muscles without consideration of their antagonists. Muscles in the body are always balanced, and both groups must be capable of active functions if the movements of either are to be effective. (Cp. section on **Remedial Exercises,** etc., at p. 292.)

4. The cure of deformities by position and exercises is, however, often a slow process in young people, and almost impossible in those who are older. Hence **Operative Treatment** is frequently required. Structures which are too short, *e.g.* tendons, muscles, etc., may be lengthened; lengthened structures may be shortened; and displaced parts put in good position, and correct alinement of limbs thereby secured. One must again emphasize, however, that the replacement of the part in good position is only the commencement of the treatment; the development of the part in its good position so as to secure normal growth of the various structures concerned is just as important an element in the treatment, and herein lies the desirability of all students and practitioners studying in themselves and in their patients the functions and methods of exercising the various muscle groups.

The consideration of many orthopædic deformities has been or will be dealt with in other appropriate sections of this work; in this chapter it is proposed merely to discuss certain conditions which for convenience are grouped together.

Torticollis.

Torticollis, or wry-neck, is a deformity produced primarily by contraction of the sterno-mastoid muscle, although in old-standing cases the trapezius, splenii, scaleni, and other deep muscles of the neck, as well as the deep fascia, are affected. It is characterized by the affected side of the head being drawn down towards the shoulder, whilst the face is turned towards the sound side (Fig. 221).

Several different types are described, in particular the acute or rheumatic, the chronic, which is usually due to cicatricial changes in the muscle, and the spasmodic.

1. The **Acute** or **Rheumatic** variety is usually the result of exposure to cold or to sitting in a draught; it comes on suddenly, and is extremely painful, and the muscle or muscles affected are tender to the touch. The possibility of mistaking it for other inflammatory affections, such as acute lymphadenitis or cellulitis, must not be overlooked; in them the neck is often fixed so as to protect the inflamed structures. **Treatment** must be general as well as local; aspirin may be given to relieve

pain, or salicylates to counteract the rheumatic poison, whilst a dose of calomel or castor oil is always beneficial. Local fomentations should be applied in the early stages, and subsequently massage.

2. The **Chronic** form of torticollis is almost always due to cicatricial changes in the sterno-mastoid, which result in its intrinsic shortening. (*a*) It is occasionally *congenital*, and then it is due to malformation or malposition *in utero*, whereby the muscle is imperfectly developed. (*b*) Most commonly it follows the *congenital induration* of the muscle (*q.v.*), due to laceration of its fibres during birth; it is therefore to be looked on as a myositis fibrosa. It is sometimes associated with winged scapula or other conditions due to injury of the muscular branches of the fifth and sixth cervical nerves inflicted at the same time as that to the sterno-mastoid. (*c*) At a later date contraction of the muscle may result from suppuration or gummatous formation within the sheath, but the deformity is then less marked.

FIG. 221.—CHRONIC TORTICOLLIS. The right sterno-mastoid is contracted, and the facial asymmetry is very noticeable.

Either the sternal or clavicular portion may be separately contracted, or the whole muscle may be affected, standing out as a hard tense band, the muscular substance being almost entirely replaced by fibrous tissue. The deep fascia is always secondarily contracted and shortened, and when the deformity has lasted long the posterior cervical muscles are similarly affected, whilst changes in the shape of the cervical vertebræ are also induced, the bodies becoming wedge-shaped, and thickest towards the convexity. A secondary compensatory curve is usually present in the dorsal spine, so as to maintain the horizontal position of the eyes. In children the affected side of the head and face also becomes atrophic. The measurement from the external canthus to the angle of the mouth is smaller, the eyebrow is less arched, the nose somewhat flattened, and the cheek less full than on the sound side. These phenomena are probably due to imperfect vascular supply, resulting from the limited mobility.

The **Diagnosis** of a chronic torticollis is readily made from the fact that the sterno-mastoid muscle is evidently contracted and stands out as a tense subcutaneous band. It must not be confounded with cicatricial contraction of the skin of the neck following burns, or with the deformity and rigidity of the neck which results from a rheumatic inflammation of the deeper ligaments and muscles of the cervical spine (rheumatic spondylitis), or from tuberculous disease of the cervical vertebræ.

Treatment.—Massage and manipulation may be first tried, or even some form of mechanical apparatus directed towards stretching the

contracted muscle (*vide infra*), but in the majority of cases tenotomy or myotomy will give a more satisfactory result, and is less tedious and troublesome.

Two methods of dividing the sterno-mastoid have been employed: (1) The *subcutaneous* operation is a desirable proceeding, as it leaves no obvious scar, but requires great care in order to avoid damage to the important underlying structures. There is but little danger or difficulty in dealing with the sternal head, a tenotome being passed down to it beneath the skin, and the incision made from before backwards; the tension to which it is exposed suffices to draw it well forward out of harm's way. The clavicular portion, on the other hand, should generally be divided through an open incision. (2) The *open* method obviates all danger, but leaves a noticeable scar, unless care is taken to suture the platysma separately when closing. The skin, about ½ inch above the clavicle, is incised across the muscle, its anterior and posterior borders are defined, and its fibres completely divided. Tense portions of the cervical fascia on its deep aspect may also be carefully cut across, keeping in view the importance of the underlying structures. The position of the head is then rectified, and for a time it is kept between sand-bags, or fixed by plaster of Paris. Later, a simple and satisfactory arrangement for maintaining the new position consists of a padded leather strap passed round the forehead and occiput, and another under the axillæ. An elastic band is secured to the forehead strap above the mastoid process of the side which is not affected, and traction made by fixing it to the front of the lower belt on the opposite side of the body. Thus, if the left sterno-mastoid is contracted and has been divided, the chain is attached above over the right mastoid process and below over the front of the left axilla, traction being thus made in the direction of the weakened right sterno-mastoid muscle. Where osseous changes are present, the deformity may persist to a great extent, in spite of combined operative and mechanical treatment.

3. **Spasmodic** torticollis is a condition which occurs most frequently in women about thirty years of age, in whom there is often a family history of insanity or nervous diseases, such as epilepsy, etc. It is characterized by clonic spasms of the various muscles of the neck, especially the sterno-mastoid and trapezius, but the deep short rotator muscles are also affected in many cases. The head is continually being twisted and jerked into a position of torticollis, but other movements are often associated. The cause is some lesion of the nervous supply of the muscles, probably in most cases cortical. In a few instances irritation of peripheral nerves, as by inflamed glands, teeth, etc., may exert some temporary influence, but the true spasmodic wry-neck persists in spite of the removal or cure of such causes. The prognosis is always very unfavourable, since, even if the localized spasm is cured by appropriate operative treatment, other parts are likely to become affected.

Treatment in these cases should be of a hygienic and tonic character; peripheral sources of irritation must be removed, and careful investigation made to ascertain that all the functions of the body are

satisfactorily performed. Intestinal toxæmia, disorders of menstruation, and any other possible causes of irritation, must be relieved. Local applications of electricity of various types may be employed, as also suitable hydro-therapeutic remedies. Not unfrequently the spasms persist, and then it may be well to divide the posterior cervical nerves, as they lie on the semi-spinalis colli.

A **Cervical Rib** is a deformity of not uncommon occurrence, generally noticed about the age of puberty. It is usually bilateral, and arises most frequently from the anterior transverse process of the seventh cervical vertebra, but a similar outgrowth sometimes occurs from the sixth. It is at first composed mainly of cartilage, but as age advances it becomes osseous. It may be short and have a free end in the neck,

FIG. 222.—BILATERAL CERVICAL RIBS.

but more frequently passes down to unite with the first rib near the scalene tubercle, or to gain attachment to the sternum; occasionally, it consists of two portions, an upper and a lower, united together by a synchondrosis. No symptoms are produced until the mass by its growth encroaches on the subclavian artery and lower and inner cords of the brachial plexus. The vessel is pushed upwards and forwards, and becomes at times so prominent as to be mistaken for an aneurism; sometimes the pulse is impaired when the arm hangs down, and this may even determine gangrene of the finger-tips. Nervous symptoms are referable to the first dorsal and eighth cervical nerve-roots, and appear in the form of neuralgia along the ulnar border of the forearm and little finger, or of weakness, mainly of the intrinsic muscles of

the thumb. A cervical rib presents as a hard swelling above the clavicle, and can be readily recognized by radiography (Fig. 222). Nothing should be done unless pressure symptoms are present, when removal may be required. An incision is made parallel to the anterior border of the lower portion of the trapezius; the nerves and vessels are separated from the swelling and drawn aside, and the growth carefully excised by gouge, chisel, or cutting pliers.

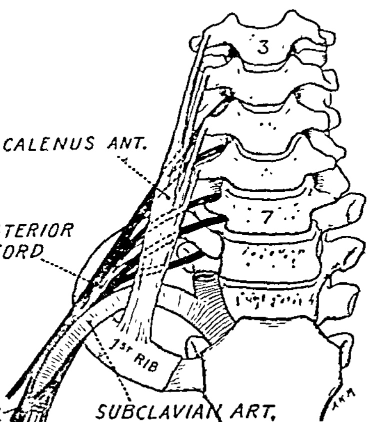


FIG. 223.—THE RELATION OF THE BRACHIAL PLEXUS, SUBCLAVIAN ARTERY AND SCALENUS ANTICUS MUSCLE TO THE FIRST RIB.

An alternative procedure, advocated by Adson, is that of division of the scalenus anticus muscle, close to its insertion into the first rib. The operation is more simple than removal of the cervical rib, and good results are claimed (Fig. 223).

Deformities of the Spine.

Scoliosis.—By scoliosis is meant a lateral curvature of the spine accompanied by rotation of the vertebræ. Conditions are met with in which the spine becomes deflected laterally as an occasional result of Pott's disease, or in fractures; these, however, are not generally considered to be genuine scoliosis.

Ætiology.—The following are the chief causes of scoliosis:

(1) It occurs very rarely as a congenital deformity, owing to malformation of the vertebræ.

(2) It may commence in young children as a result of *rickets*, owing partly to the softened condition of the bones, partly to their irregular growth. It is probably often induced by the children being always carried on the same arm, and the primary curve is usually in the dorsi-lumbar region.

(3) Any condition of asymmetry of the body may lead to what is known as *compensatory scoliosis*, *e.g.* congenital shortness of one leg, unilateral dislocation of the hip, contraction of the knee- or hip-joint, genu valgum, falling-in of the chest wall as a result of empyema, unilateral paralysis of spinal muscles in infantile palsy, and even old-standing torticollis. If one leg is short (Fig. 224), the pelvis is tilted down on that side in order to bring the foot to the ground, producing a lumbar curve with the convexity towards that side, and then a compensatory dorsal curve in the opposite direction is subsequently added in order to maintain the general axis of the body (A′). If, however, the short leg is also persistently adducted, as in old hip disease (Fig. 225, B), the spine will be curved in the opposite direction in order to maintain the parallelism of the limbs (B′).

(4) The most common type, however, is the *static* (or *postural*)

scoliosis of adolescents, who are in a weak and asthenic condition, often as a result of rapid growth, combined possibly with improper or insufficient food, defective hygienic surroundings, or exposure to hard work, whereby undue muscular fatigue is induced. Young women of an anæmic type who suffer from amenorrhœa, and who as housemaids or factory hands have to undertake a good deal of lifting, are liable to this condition, and especially if their work involves a maintained position of lateral deflexion of the spine. It is largely due to a relaxed state of the ligaments and muscles, which have not developed *pari passu* with the weight and length of the skeleton, and is therefore not unfrequently associated with flat-foot and genu valgum. Prolonged standing in a position of ease or rest, in which the weight of the body is mainly carried on one leg, may determine its occurrence. School children develop this deformity readily as a result of the persistent adoption of faulty positions during reading or writing, owing to low desks and want of support to the

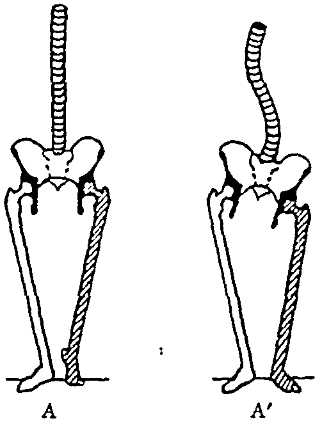


Fig. 224.—Scoliosis due to Shortening of the Left Leg.

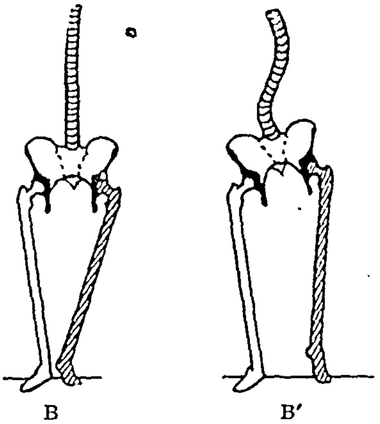


Fig. 225.—Scoliosis due to Adduction of the Left Hip.

feet. In addition to all these local phenomena, however, must be remembered the fact that the mental outlook of the majority of these patients is one of depression or pessimism, leading to a slouching gait with round shoulders and a prominent abdomen; the depressed state of her mind manifests itself in a relaxed habit of the body. A happy, hopeful outlook on life helps to produce an upstanding frame of body with ‘ chest out and shoulders back.’

The **Phenomena** vary considerably according to the character and extent of the lesion. Sometimes the whole spine is involved in one curve (*total* scoliosis); but more usually two curves are present, one primary, the other compensatory. It is by no means uncommon for this condition to be associated with kyphosis, but the absence of the latter, in what is sometimes termed the ‘ flat-backed ’ type, is no criterion of the slightness of the case. The most usual variety is that in which there is a double curve, with the dorsal convexity to the right and the lumbar to the left (Fig. 226). It will be desirable to

describe this carefully, whilst for the opposite condition (Fig. 227) all that is necessary is to transpose the words 'right' and 'left' or, as Hoffa has put it, one variety is the 'mirror picture' of the other.

In addition to the lateral displacement, *the bodies of the vertebræ* are always *rotated* towards the convexity of the curves. This also occurs to some extent in normal flexion of the spine, and is a purely mechanical act, and due to the more firm support given to, and the interlocking of, the posterior parts of the vertebræ. As a result, the spinous processes are directed towards the concavity, and hence

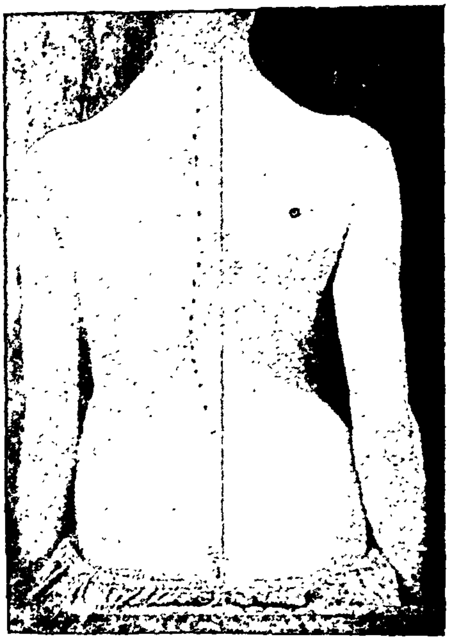


FIG. 226.—SLIGHT SCOLIOSIS (TOTAL TO LEFT SIDE).

FIG. 227.—MARKED RIGHT-SIDED SCOLIOSIS.

always indicate a smaller amount of distortion than really exists. Occasionally there may be some backward projection of the spines at the junction of the two curves.

The *thoracic walls* necessarily participate in the process, and the amount of thoracic deformity is perhaps the best measure of the degree of rotation of the vertebræ. The ribs on the right side become to some extent separated from one another, and project posteriorly on account of this rotation (Fig. 228); the amount of curvature at the angle is consequently increased, whilst the front of the chest on this side of the body becomes flattened. On the left side the ribs are huddled together, and the curve at the angle diminished, the ribs being thereby opened out; consequently, the thorax is flattened posteriorly on that side, but projects in front; the left breast may thus be rendered prominent. In fact, the thorax becomes more or less rhomboidal in shape. The sternum also is somewhat displaced

towards the concavity, and twisted so that the anterior surface looks towards the right. The capacity of the thorax is not as a rule affected at first, but in the later stages it is considerably diminished, and the abdominal viscera may even be displaced. The *scapulæ* follow the thoracic wall, and hence the right shoulder is pushed upwards and outwards, and it is for this 'growing out of the shoulder' that the majority of cases come under observation. The effect on the *waist* varies with the situation and extent of the curves; if the dorsal and lumbar curves are nearly equal, then the true waist on the right side becomes more marked than usual, corresponding to the lumbar concavity, and in advanced cases a distinct sulcus may be present between the lower ribs and the crest of the ilium. On the left side the hip appears to project ('growing out'), owing to the deflection of the trunk towards the right side (Fig. 227), whilst the dorsal concavity higher up may simulate a false waist. The erector spinæ muscle stands out unduly on the left owing to the rotation of the vertebræ, whilst the transverse processes on this side may be unusually evident.

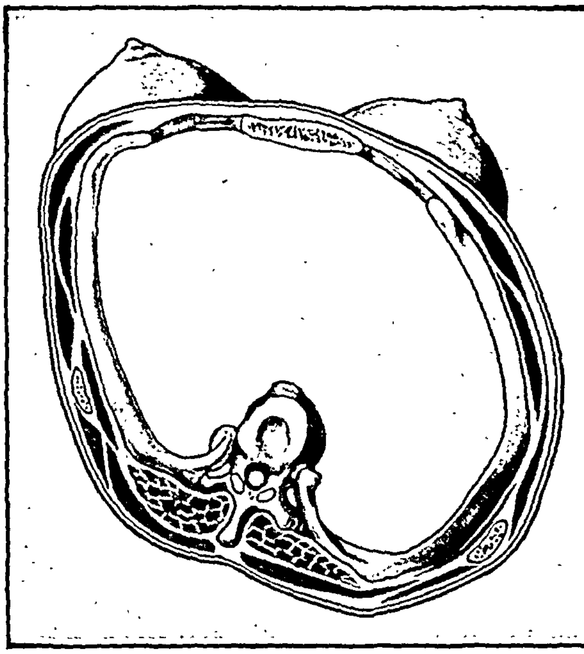


FIG. 228.—SECTION OF THORAX IN SCOLIOSIS WITH DORSAL CONVEXITY TOWARDS THE RIGHT SIDE.

In the early stages the characteristic deformity disappears on extension of the trunk, as by hanging from a trapeze, or on bending forwards; but as the condition progresses, the spine becomes more and more fixed, and but little alteration is produced by suspension of the patient. In the worst cases, especially when associated with kyphosis, the deformity becomes so marked as to simulate the 'hump' formed in Pott's disease, and the patient's stature becomes dwarfed and stunted.

Subjective symptoms, such as neuralgic pain and weakness, are also present, but usually they are not very prominent features.

Anatomical Changes occur only in the later stages of the case, and conform to the general rules of such deformities. At first it is merely the muscles and ligaments that become affected in the direction of shortening on the side of the concavity and lengthening and relaxation on that of the convexity; these are merely accommodative phenomena. Later on, the vertebræ themselves may become misshapen, and wedge-like on section, being thicker on the convex than on the concave side. The intervertebral

discs are similarly changed, whilst the articular processes are unduly pressed together on the concave side and separated from one another on the convex. The transverse and spinous processes are also approximated to one another on the side of the concavity and often curved.

It is most essential that a correct **Diagnosis** be made as soon as possible, since so much depends upon early treatment. A thorough examination should be made with the patient standing and the clothes stripped to below the waist, so that the whole back can be seen. The general appearance is first noted, and then the spinous processes are marked out one after another with a spot of ink or with a flesh pencil. The shape of the thorax, the curvature of the ribs, and the position of the scapulæ are also ascertained, and the length of the legs is measured. The patient is then made to hang from a bar, and to bend forwards, and the effects of these respective movements noted; by this means some idea can be obtained of the extent and nature of the deformity. There can be but little risk of mistaking it for Pott's disease, since the rigidity, deformity, and localized pain of the latter are so characteristic; in bad cases of scoliosis, however, where there is a projection of the spinous processes backwards, a mistake might easily arise if only a careless examination were made.

The **Prognosis** necessarily varies with the stage which the affection has reached. In early days, before the deformity has become set, and when it disappears on extension of the spine, it is almost certain to be entirely cured, if suitable precautions are taken. Later on it can be improved to some extent, but in bad cases all that can be expected is to prevent it from getting worse.

In the **Treatment** of scoliosis, the cause of the trouble must not be overlooked, since in many cases the deformity may be remedied, or at any rate prevented from increasing, by attending to this. Thus, inequality in the length of the limbs necessitates the wearing of a high-heeled boot, whilst contractions of the knee- or hip-joints should, if possible, be corrected. In that variety which occurs in young people from constitutional or local debility, the general health must be improved by suitable measures. Carefully-regulated rest and exercise must also be recommended, so as to improve the muscular tone of the back without unduly fatiguing the patient; for a similar reason massage and cold baths are beneficial. All errors of position must be corrected, and suitable desks, forms, and chairs utilized. In the slighter cases it often suffices to order the patient to rest in the supine position on an inclined board for an hour or two daily, the head being thus raised and the spine extended. Remedial exercises constitute the most important element of treatment, which may be looked on as curative in early and moderate cases, and as palliative in the advanced stage. Some of these are arranged so as to extend and render mobile the spine, and generally to improve the tone of the spinal muscles; others are devised so as to undo the abnormal curves present. Space forbids us describing them here, and we must refer readers to special textbooks.

A spinal support is occasionally useful, but should not be worn continuously, except in bad cases, as it renders the muscles of the

back weak from disuse. All that is needed in the early stages is the support of a firm, carefully-fitted corset; but should the deformity increase, stronger instruments may be employed in which springs are incorporated, whereby it is hoped that correction of the curvature may be brought about. In the worst cases, where the deformity is irremediable, much can be done by a skilful mechanism to hide the deformity and prevent its increase; Albee's operation (*q.v.*) may also be useful for this purpose.

Kyphosis.—By this term is meant a condition of increased dorsal convexity of the back which is often associated with loss of the lumbar concavity, so that the whole spine is arched backwards. Occasionally, however, a marked lumbar lordosis is present as a compensatory condition.

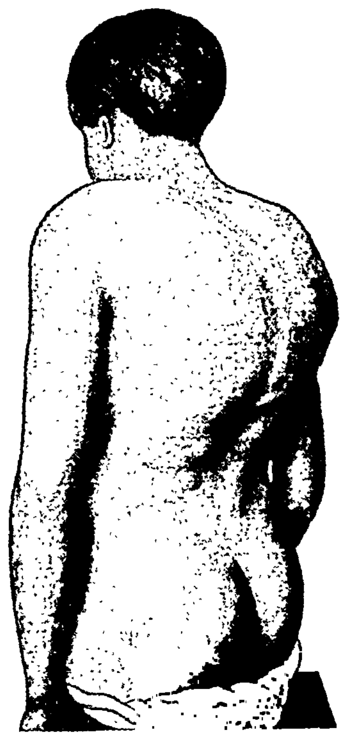


FIG. 229.—ACQUIRED OCCUPATION KYPHOSIS IN A YOUNG MAN FROM EXCESSIVE WEIGHT-CARRYING.

The chief **varieties** of kyphosis are as follows:

1. Kyphosis from defective growth or habit. This may occur (*a*) in children under the age of four, resulting from rickets; (*b*) in adolescents up to the age of sixteen (round shoulders), from a continuous habit of stooping, as in reading or writing, especially in those suffering from myopia; (*c*) various forms of occupation which involve the carrying of heavy weights, or stooping over work, lead to its appearance in adults, as in porters and cobblers (Fig. 229); (*d*) in old men it results from senile atrophy.

2. Kyphosis from general disease of the spine is a marked feature in spondylitis deformans, osteitis deformans, osteomalacia, hypertrophic osteo-arthropathy, and acromegaly. In the latter disease the condition is limited to the dorsal region.

3. Kyphosis also arises from localized injury or disease of the spine, *e.g.* traumatic spondylitis, fractures, Pott's disease, gumma, or cancer.

Treatment is impossible in the majority of cases, but the round shoulders of young people come so commonly under observation that a little more notice of the condition is needed.

Round Shoulders occur most frequently in girls who have grown rapidly, and perhaps developed precociously. The condition is often due to defective habits of sitting and standing, especially at school, and may be induced by faulty desks and chairs, but other conditions, such as myopia or adenoids, may be primarily responsible. The deformity can be voluntarily corrected in the earlier stages, but not so later on.

Treatment.—In the first place the cause must be ascertained, and if possible removed; chairs and desks must be arranged so as to ensure that the child sits in a good position, and does not stoop when writing, reading, or playing the piano. In particular, the back should be supported whilst reading, and the feet should not be allowed to dangle. The muscles of the back, especially the trapezii, the erectores spinæ, the rhomboidei, and the serrati, must be strengthened by massage, electricity, and exercises, the latter necessarily directed towards extension of the back. Undue fatigue must be avoided, and the girl should rest on her back two or three times a day for half an hour. At night she should lie on her back, without a pillow, and with a pillow beneath the curve. The general nutrition and health must also be attended to, and a course of suitable tonics prescribed. In bad cases where the deformity is marked and it is feared it may be progressive, a light support may be required; but of course the exercises must be persisted in.

Lordosis is almost invariably a secondary or compensatory condition, and consists in an increased anterior curvature of the spine in the lumbar region. It is usually produced by continued flexion of the hip, whether due to congenital displacement, unreduced dislocation, malunited fracture, or to hip disease, and is irremediable unless the malposition of the femur can be corrected.

It is seen as a temporary condition in pregnancy, and as a more persistent phenomenon in bad cases of uterine fibroids, owing to the increased weight of the uterus or its contents, necessitating backward displacement of the upper part of the spine in order to adjust correctly the centre of gravity of the body. The same may be noticed in persons with large, fat, and pendulous abdomens.

It is occasionally present in progressive muscular atrophy where the lumbar and abdominal muscles are weakened, and usually in pseudo-hypertrophic paralysis from loss of power in the gastrocnemii and other muscles engaged in maintaining the erect posture.

Spondylo-listhesis is the term applied to a curious and somewhat uncommon deformity, in which the lumbar vertebræ slip forwards and downwards from the top of the sacrum. It arises from fracture of the articular processes of the lumbo-sacral joints, or from imperfect development of the laminæ or pedicles of the lowest lumbar vertebra, as a result of which the pressure of loads carried on the shoulders or the weight of a pregnant uterus brings about the displacement. In the latter instance the enforced lordosis aggravates this tendency. The effects produced are shortening of the stature, together with the formation of a marked hollow above the sacrum, whilst the lumbar vertebræ are unduly prominent anteriorly. The condition is accompanied by neuralgic pain and weakness.

Treatment.—In suitable cases operative treatment by driving a bony peg from the fifth lumbar vertebra into the sacrum, when the deformity has been corrected by weight extension applied to the legs, is curative. An Albee's bone graft is usually insufficiently strong to prevent the recurrence of the displacement. In other cases prolonged rest may be tried, with possibly the application of a leather

jacket moulded to the pelvis and supplied with crutches so as to carry part of the weight downwards from the axillæ to the pelvic support without utilizing the spine.

Deformities of the Upper Extremity.

In **Congenital Elevation of the Scapula** (Sprengel's shoulder) the scapula may be normal in size or a little smaller than usual, but is situated above its proper position, and rotated so that its lower angle is approximated to the middle line. The muscles attached to its upper border are prominent; in a few instances a cartilaginous or osseous band has replaced them, passing between the upper angle or the bone and the seventh cervical vertebra. The lower third of the trapezius is often defective, as also the serratus magnus. The disability, which is usually slight, depends on the condition of these

FIG. 230.—WINGED SCAPULA.

muscles, but the affected arm is sometimes smaller than its fellow. A slight degree of scoliosis develops as a compensatory phenomenon. The only active *treatment* consists in dealing with the affected muscles by removing the cartilaginous or osseous band; otherwise massage and exercises are required.

A **Winged Scapula** is a condition characterized by projection backwards of the vertebral border and lower angle of that bone when the arm is thrust forwards (Fig. 230). It is due to paralysis of the serratus magnus and rhomboids, which normally keep the venter of the scapula in contact with the chest wall. It may be due to injury or division of the nerve of Bell in the axilla, or to irritation and compression of the fifth and sixth cervical nerve-roots, which may be tender; weight-carrying on the shoulder may also be responsible for this lesion. **Treat-**

ment consists in massage and faradism, whilst, if persistent, a suitable appliance may correct the deformity. Sometimes improvement results if a part of the pectoralis major is sutured to the axillary border of the scapula.

A curious **Tilting** of the **Scapula** occurs in children where the spinal accessory nerve has been divided during operations on the neck, as for tuberculous glands. When the arm is raised or pushed forwards, the normal relation of the scapula to the spine is not maintained, owing to paralysis of the trapezius, but the bone is tilted upwards and outwards, so that a considerable hollow develops immediately behind the clavicle. It is unsightly, but not especially detrimental, and with growth and active exercise any ill-effects usually dis-

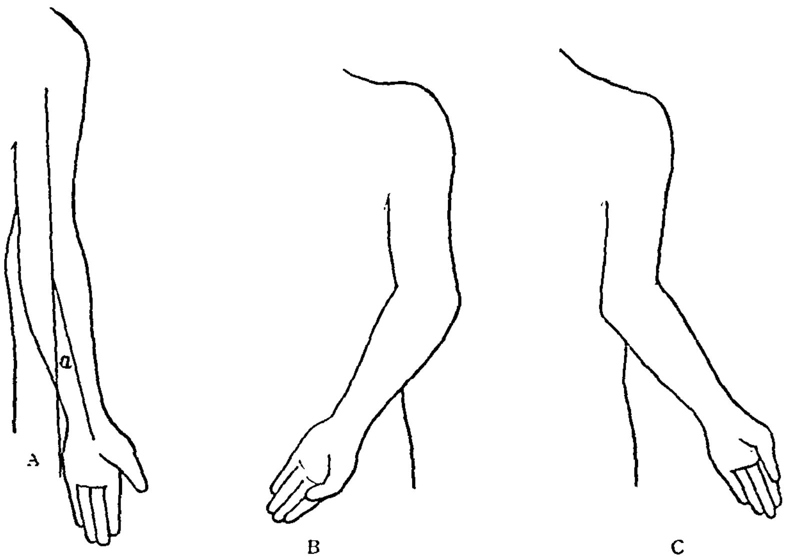


FIG. 231.—OUTLINES OF UPPER EXTREMITY TO SHOW—A, NORMAL CARRYING ANGLE ($a=15°$); B, CUBITUS VARUS; C, CUBITUS VALGUS.

appear. As a rule treatment is unnecessary, but if need be an attempt must be made to find and unite the divided ends of the nerve.

Cubitus Valgus and Cubitus Varus.—Under normal conditions the axis of the forearm does not correspond with that of the arm, the former being in a position of slight abduction (about 15°), constituting what is known as the 'carrying angle' (Fig. 231, A). This angle is often greater in women than in men, and when marked constitutes the condition of *cubitus valgus* (C). This is usually due to a fracture of the external condyle of the humerus in children. The damage to the epiphysis results in impaired growth. Normal growth occurring on the inner side of the joint causes gradual increase of the carrying angle. Similar deformity may result from operative removal of the head of the radius. Occasionally a fracture of the inner condyle of the humerus, with downward displacement of the fragment, may cause cubitus valgus. The ulnar nerve is likely to become unduly exposed

beneath the skin, and thus to suffer recurring injuries of a neuritic type. If the causative bony lesion cannot be repaired, the nerve should be set free and displaced in front of the condyle. *Cubitus varus* (B) is due to similar lesions of the inner or outer condyle.

In rare cases a supracondylar osteotomy may be required to correct the deformity.

Madelung's Deformity is a condition more commonly seen in females and probably associated with injury, and consists of a deformity of the growth of the lower end of the radius whereby the carpus is pushed laterally and towards the palm without an associated movement of abduction or lateral twist. It may be uni- or bi-lateral and is accom-

Fig. 232.—Bilateral Club-hand due to Congenital Absence of Radius. Thumbs entirely absent.

panied by a limitation of movement of the wrist joint, especially as regards dorsiflexion, and a weakness of all movements. Exercises and support by a moulded leather appliance extending the length of the forearm down to the metacarpo-phalangeal joints should be employed.

Various types of **Club-hand** occur, in which the hand is deflected to one or the other side, or is hyper-extended or flexed. Perhaps the most frequent cause is a *congenital absence of the radius* (Figs. 232 and 233), under which circumstances the hand is radially abducted to a marked degree, the ulna is shortened and curved, and its lower epiphysis expanded so as to articulate with the carpal bones. Where the bones are normal, the hand is usually flexed and adducted towards the ulnar side. In all of these deformities radiography should be employed so as to ascertain the exact relation of the bones to each

other. Congenital absence of the ulna occurs also, in which condition there is a manus varus deformity.

Congenital Deformities of the Finger are much more common, and the account here given of such defects of the upper extremity applies with equal force to those which occur in the lower. The following varieties may be alluded to:

Polydactylism consists in the presence of supernumerary fingers and toes. There may be from one to seven additional digits, and the condition is usually symmetrical. The accessory digits are often stunted, and smaller in size than the normal, but may be of average dimensions. Usually they are separated from the true digits, but

FIG. 233.—X-RAY OF CLUB-HAND DUE TO CONGENITAL ABSENCE OF RADIUS.

now and then may be blended with them. The correct number of metacarpal or metatarsal bones may be present, or they also may be multiplied. In one of our cases there were six digits and six metatarsal bones; but the last two digits were supported by an accessory metatarsal apparently springing from the outer side of the fourth. The condition is frequently inherited. The **Treatment** consists in removing the supernumerary digits, if useless, obtrusive, or troublesome. Sometimes the patients are proud of their abnormality, and refuse to part with it.

Ectrodactylism, or the absence of one or more of the digits, is occasionally seen, as also partial arrests of development of fingers or toes, or intra-uterine amputation at a higher level.

Macrodactyly (Fig. 234) consists in a congenital overgrowth of one or more fingers or toes. The structures are perfectly normal in

character, and merely gigantic in size for the age of the individual. Amputation or excision may be needed in these cases, as the deformed parts grow out of all proportion to the neighbouring tissues. Thus, an infant with enormous overgrowth of the second toe of the right foot was successfully treated by excision of the digit, together with a V-shaped portion of the foot, which was by this means reduced to normal shape and size.

Syndactylism, or webbed fingers, is a condition in which two or more fingers are joined together laterally, either by a thin web consisting mainly of skin, or by a thick fleshy bond of union. In the foot no *treatment* is required, but in the hand the fingers must be separated. If there is merely a thin web, this may be divided by scissors; but to prevent its re-formation from above downwards, as healing proceeds, a flap of skin must be transplanted into the angle between the fingers, or an opening in the base of the web may be made and maintained, and the edges allowed to cicatrize before the web itself is divided. Where the union, however, is thick and fleshy (Fig. 235), a more extensive operation is needed. Two flaps of skin as long as the web, and half the width of a finger, are respectively raised from the dorsal aspect of one finger (Fig. 236, A) and from the palmar aspect of the other (B) in such a manner that, after the web has been divided, the denuded surfaces can be covered by wrapping the flaps round the lateral aspects of the fingers and suturing them in position. An additional flap of skin must also be fixed in the angle between the separated digits. Agnew's operation consists in isolating a triangular piece of skin from the dorsum of the web, the apex of which is situated half-way up the latter and the base over the heads of the adjacent metacarpals. The rest of the web is then divided, and the flap brought forward and sutured to a suitably prepared bed on the palmar aspect. This flap prevents any union by granulation tissue at the bottom of the web.

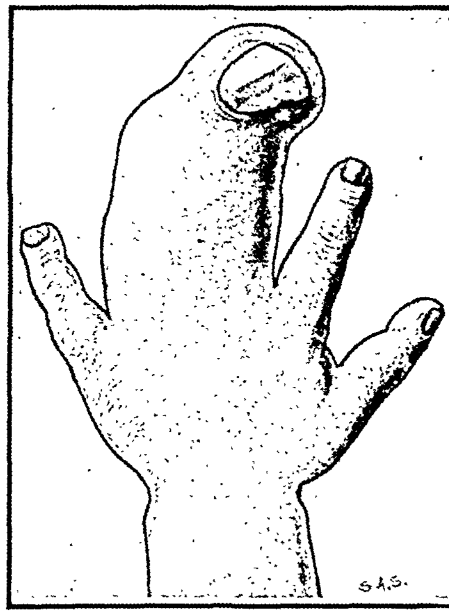


FIG. 234.—MACRODACTYLY AND SYNDACTYLY.

In this case a child, aged two and a half years, had the ring and middle fingers united laterally into a large mass which projected far beyond the others. The middle finger was normal in size, the ring finger was hypertrophic. A fruitless attempt was made to save the middle finger, but both had finally to be amputated.

A similar condition is occasionally developed after burns or wounds involving the webs between the fingers. It is usually preventable if the fingers are kept well apart and early skin-grafting is undertaken. Otherwise the scar must be divided and the raw surface produced

thereby grafted, or operative treatment more or less similar to that described above undertaken.

Congenital Contraction of the Fingers is not a very rare deformity, being frequently inherited; it is usually limited to the little finger, and may be associated with congenital hammer-toe. It is due to contraction of the *central* prolongation of the palmar fascia in the finger, whereas Dupuytren's contraction involves the palmar fascia itself and its *lateral* prolongations into the fingers. Moreover, in the congenital variety the first phalanx is hyper-extended, and the second and third flexed, whereas in the acquired form the first and second phalanges are flexed and the third is hyper-extended.

Treatment.—It often suffices to use massage and apply a splint, but in bad cases division of the fascial bands may be needed.

Acquired Deformities of the Hand.—After burns the hands may be contracted into a useless mass in which the fingers are drawn into the palm and united by cicatricial tissue to the palmar structures, so that all treatment is hopeless.

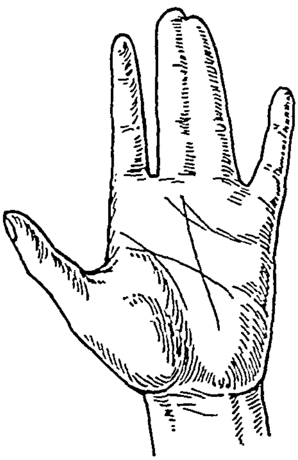


FIG. 235.—SYNDACTYLY.

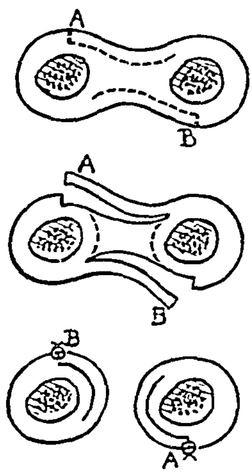


FIG. 236.—OPERATION FOR SYNDACTYLY.

For deformities due to damage to the tendons of the fingers, see p. 463.

Spring-, Jerk-, or Snap-finger is a condition in which, when the patient attempts to open his hand, one finger or the thumb remains flexed, and on extending it with the other hand it flies open with a jerk or snap. Slight tenderness is usually felt near the metacarpo-phalangeal articulation, and the cause of the trouble is some obstruction to the free working of the long tendons under the transverse ligament at the root of the fingers, or between the sesamoid bones of the thumb. In a few cases a ganglion has been present here, but in most instances the condition is due to an increase in size of the sesamoid bone, which radiography has taught us occurs constantly in this situation. **Treatment** consists in an aseptic incision to remove the cause of the obstruction.

A **Mallet Finger** (' base-ball finger ') is one in which the terminal phalanx is maintained in a state of flexion owing to some damage to the extensor aponeurosis. Its **treatment** in the early stage has been already alluded to (p. 463); should the deformity be persistent, an incision is made on the posterior aspect of the finger, and the weak tendon isolated and stitched down in such a way as to give it a better attachment to the bone.

Contraction of the Palmar Fascia (Dupuytren's Contraction).—This condition is usually met with in middle-aged individuals of a gouty

temperament, more often in men than women, and not unfrequently on both sides of the body. It may or may not be associated with direct irritation of the palm, as by leaning much on a round-headed cane, or from the constant use of some instrument, such as an awl, whilst heredity is an important causative factor. Pathologically, it is due to a chronic overgrowth and contraction of the fascia, inflammatory in nature, and cirrhotic or sclerosing in type. It commences as an indurated subcutaneous nodule in the palm of the hand, about the situation of the most marked transverse crease, and affects most commonly the ring and little fingers first, the other fingers and thumb being less often involved. The induration spreads slowly both up and down the fascial bands into the fingers, and may even extend downwards beyond the normal limits of this structure, so as to cause acute flexion of the second phalanx, as well as moderate flexion of the first. The whole finger is thus gradually drawn into the palm and fixed, so

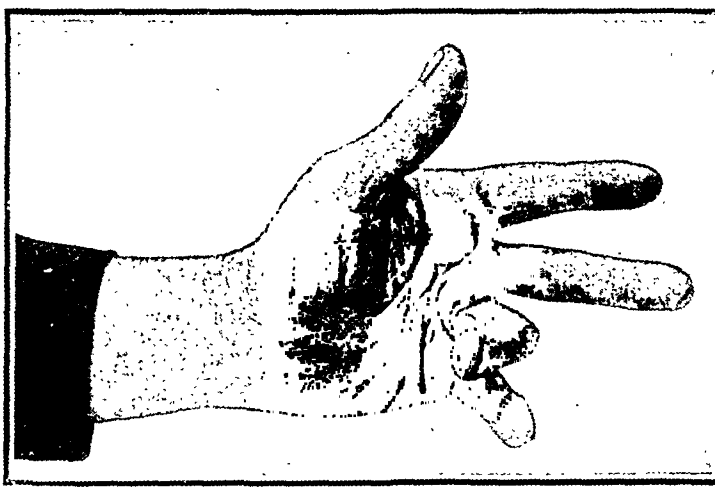


FIG. 237.—DUPUYTREN'S CONTRACTION.

that extension becomes impossible (Fig. 237). The third phalanx always remains extended, and, indeed, sometimes assumes a position of hyper-extension, owing to the injudicious application of a splint. The skin over the indurated masses is sooner or later incorporated with them, and may become dimpled or creased by the traction of the subcutaneous connecting bands.

The **Diagnosis** of Dupuytren's contraction is exceedingly easy, the only condition for which it is likely to be mistaken being the congenital contraction already noted, and the flexion of the finger due to contraction, division, or destruction of the long tendons. In the latter case there is, as a rule, no palmar induration, but there will be a history of injury or inflammation, and some scarring.

The only satisfactory **Treatment** is by operation; and the following methods are those which are most successful: (*a*) Adam's subcutaneous section of the fascia and its prolongations consists in dividing the indurated bands by a tenotome in several places, where they can be felt tense. One puncture and division must be made in the centre

of the palm, a second divides the same band as near the finger as possible, whilst the third and fourth deal with the lateral prolongations at the sides of the finger; if other bands still exist, they are treated similarly, the tenotome, if possible, in all cases being inserted between the skin and the fascia. The improvement thus produced must be maintained and increased by the subsequent use of suitable apparatus and passive movements, but the final results are not very satisfactory. (*b*) Kocher's method consists in the total extirpation of the thickened bands and their prolongations through longitudinal incisions. The fingers may be subsequently straightened with ease, but not unfrequently the first interphalangeal joint remains flexed in spite of mechanical appliances and massage. In old-standing cases, arthritic changes in the interphalangeal joints and tightness of the skin make correction of the deformity difficult. If, therefore, the flexion persists after effective removal of the fascial bands, it is wise to excise at the same time the head of the first phalanx and shorten the extensor tendon through a transverse or semilunar dorsal incision. In this way it should be possible to straighten the fingers completely when the operation is finished. A splint must be applied whilst the wounds are healing, and a night splint must be worn for several months, or recurrence is likely to take place, but early movements and massage are required if a good functional result is to be secured.

Deformities of the Lower Extremity.

Congenital Dislocation of the Hip is a condition in which, owing to a developmental defect in the superior acetabular rim, there is upward displacement of the head of the femur. In certain cases there is a deficiency in the muscles attached to the upper end of the femur whereby they become fibrosed and pull the head out of the acetabular cavity as growth occurs, but even in these cases there is usually an associated bony aplasia. The condition is occasionally bilateral. Most commonly occurring in females, the disease has a definite geographic distribution, being so frequent in Italy as to be looked for in newborn babies. Some cases, however, will not show themselves at birth, the head being forced out only when walking occurs, the displacement being progressive until it is well above the acetabulum. In addition to the deficiency of the lip of the acetabulum, it is shallow and ill-formed, this perhaps being due to the absence of the moulding pressure of the femoral head. The capsule is stretched across it and attached to it by fibrous tissue adherent to the ligamentum teres, this tissue serving as an obstruction to reduction (Fig. 241). The inferior aspect of the capsule becomes very thickened, because it in great part is bearing the body weight. The femoral head at first appears to be normal, but becomes flattened or even conical, the neck being anteverted with a varus deformity (Fig. 240). There may be a general underdevelopment of the affected limb and a shortening of the adductor group of muscles and the hamstrings which further interfere with reduction. At birth it may be noted that there is asymmetry on the two sides, the trochanter on the affected limb being

more prominent and raised slightly. On account of this upward and outward displacement there is separation of the upper part of the thighs, with apparent widening of the perineum (Fig. 238). Usually, however, it is not till the child starts to walk that the condition is diagnosed. It is then noticed that the child walks with a curious limp. If the condition is bilateral it is a waddle rather than a limp, whereas if one side only is affected there is a lurching to the affected side. The raising and prominence of the trochanter will be apparent, and in bilateral cases a marked lumbar lordosis (Fig. 239).

On examination the shortening of the affected limb can be determined by measurement from the umbilicus. Measurement from the great trochanter will show this to be largely apparent, although, as mentioned above, the under-development of the limb may give rise to true shortening. If the affected leg is pulled upon, a certain amount of telescoping will be demonstrated. *Trendelenburg's sign is positive.* This is obtained as follows. The patient is first made to stand on the sound leg, and it will be seen that a slight normal lifting of the buttock, corresponding to a tilting sideways of the pelvis, occurs. When the body weight is supported by the affected limb, the buttock on the sound side drops because the gluteal muscles are working at a mechanical disadvantage and cannot tilt the pelvis normally. This sign is not diagnostic for dislocation of the hip joint, but occurs in any condition where a varus deformity exists. X-ray examination sometimes reveals an obvious dislocation with the shallowing of the acetabulum, but where any doubt arises the following test may be applied (Fig. 240). Two lines are drawn, one through the clear area of the acetabulum, the other at right angles through the superior edge of the acetabular margin. A normally placed femoral head lies below the horizontal and inside the vertical line, whereas a dislocated head lies outside the vertical and above the horizontal.

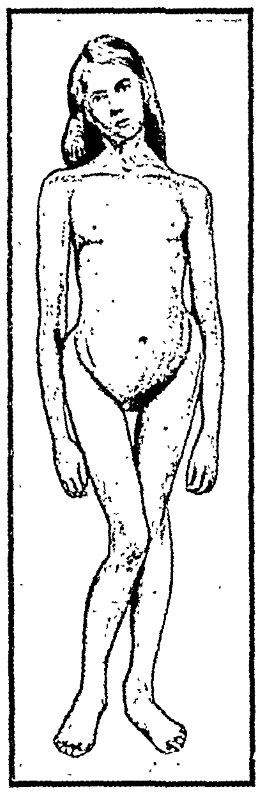


FIG. 238.

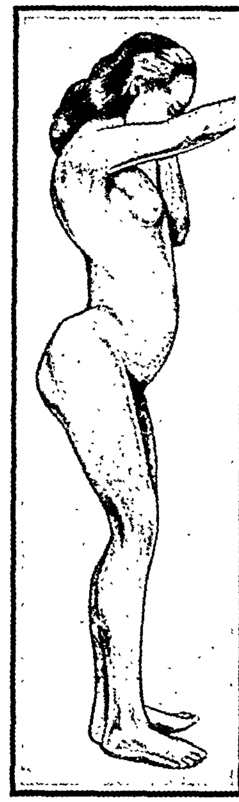


FIG. 239.

CONGENITAL DISLOCATION OF BOTH HIPS IN A GIRL OF FIFTEEN YEARS, SEEN FROM THE FRONT AND SIDE.

Treatment.—As in that of congenital deformities of the feet, treat-

ment should be instituted from the earliest possible date after birth; but this implies, of course, efficient and early diagnosis. Putti, in Italy, has shown that up to the age of about twelve months cures can be effected by abducting both limbs and keeping them in a position of abduction by a suitable splint for from eight to twelve months. The splint is an adjustable one allowing for gradual increases of abduction. In older children the hip must be reduced manually. The child is placed on her back, the knee flexed to a right angle and the thigh up towards the abdomen. Medial rotation of the thigh and abduction is then performed, the trochanter at the same time being pushed forward, reduction being recognized by the click that results

FIG. 240.—CONGENITAL DISLOCATION OF LEFT HIP-JOINT.

Note the shallow acetabulum and the impression on the ilium above the acetabulum, owing to pressure of the femoral head, which is flattened. Note also the small size of the left femur as compared with the right.

as the head passes into the acetabulum, also by the fact that with reduction the full extension of the knee cannot be performed on account of the rigidity of the rather shortened hamstrings. A plaster spica is then applied, with the thigh in a position of 90° of flexion and 90° of abduction, and 0° of rotation, the 'so-called' 90-90-0 position. This plaster extends from the umbilicus and includes both legs down to the ankle, the knees being bent to a right angle. The plaster must be effectively padded, and it is an added advantage in keeping it clean to rest the child on a metal-frame bed. This plaster is maintained for about three months, when it is replaced by another in which the adduction is reduced by about 25° if all is well. A further plaster is

applied, until at the end of nine months to a year a cure will have been effected. This method is suitable only for children up to the age of six years. In patients older than this open operation gives better results. Where bilateral dislocation exists both joints may be treated at the same time where reduction is easily attained. If difficulty is experienced, it is probably better to treat one hip for three to six months before an attempt is made to reduce the opposite side. In the old Lorenz method of reducing this deformity the joint was forcibly manipulated if the reduction was not easy, but the danger of this method is that not only are the soft tissues damaged and the adductors probably torn, but in addition the head of the femur is permanently injured, so that a mobile hip is very unlikely to result. Where reduction is not easy open operation is advised. The hip joint is exposed

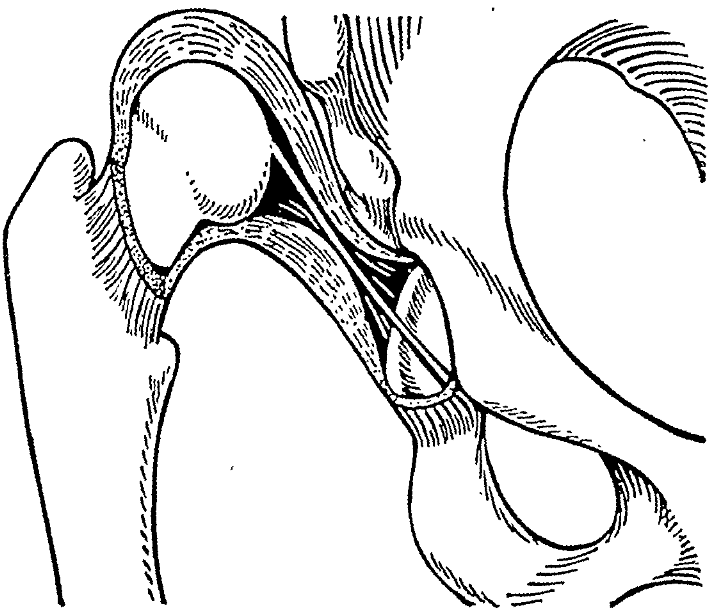


FIG. 241.—DIAGRAMMATIC SECTION OF CONGENITAL DISLOCATION OF HIP, SHOWING THICKENING OF CAPSULE AND LENGTHENING OF ROUND LIGAMENT.

by a Smith Petersen incision and division of an hour-glass-shaped capsule may be essential for reduction. In addition the opportunity is taken to reform an adequate superior margin to the acetabulum. This is effected by levering down the bone immediately above the superior acetabular margin, so that the curvature of the latter over the femoral head is approximated to normal. The rather crescentic bony deficiency left following this procedure is filled with a bone graft removed from the outer table of the dorsum ilii.

The limb is put up in plaster in abduction, which should be maintained for about four to six months, when weight-bearing may gradually be recommended. In those who present themselves after the age of fourteen years, on account perhaps of the severe limping and pain, operative intervention should be considered; but these procedures are only palliative, and a careful consideration as to whether improve-

ment is likely must be made. Of the operations, Lorenz's bifurcation operation is probably the best. In this a rather oblique osteotomy is carried out just below the lesser trochanter, and by abduction and by levering the upper end of the distal femur inwards this is made to impinge on the lower acetabular rim. The limb is then put up in slight abduction for three months, when union will have taken place between the two fragments. Part of the weight of the body now passes directly through the acetabulum to the femur, and the pain caused by the soft parts having to take the weight is relieved. In addition the limp is improved.

Coxa Vara is not a specific disease, but the name given to a condition in which the normal angle that the femoral neck makes with the shaft is reduced. Such a condition will eventually lead to osteo-arthritic changes in the hip-joint, because the head is displaced downwards and only the superior surface is articulating in the acetabulum (Fig. 242). There is in all cases a raising of the great trochanter, which often appears more prominent, and this is associated with true shortening of the limb. This is compensated by a tilting of the pelvis, with the result that the patient walks with a limp. Trendelenburg's sign may be positive because of the interference with the action of the abductor muscles. Coxa vara is produced by disease or trauma affecting either the epiphysis, head, neck, or the trochanteric region of the femur. Thus it is associated with a slipping of the epiphysis (*vide infra*), Perthes' disease, tubercle, rickets, osteomalacia, Charcot's disease, arthritis deformans, osteitis fibrosa, fracture of the neck of the femur with malunion and other conditions.

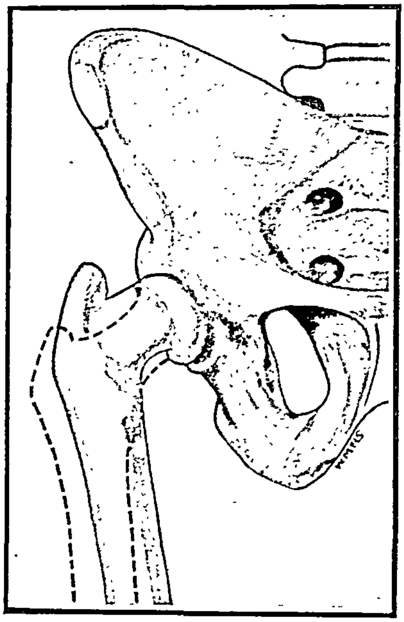


FIG. 242.—COXA VARA.
The dotted lines represent the normal neck of the femur.

Epiphyseal Coxa Vara (Slipped Epiphysis).—In this condition there is a partial or complete downward displacement of the epiphysis of the head of the femur. It occurs most commonly in males of fourteen to sixteen years of age. Sometimes a history is given of previous definite trauma to the hip which may have occurred just recently or several months ago. Often, however, no such history is given, and the patient's attention is drawn to his condition by the fact that he gets tired easily, may notice pain in the hip or referred down to the knee, and observes that he is developing a limp. On examination of the limb true shortening will be noticed, and limitation of the movements of abduction, internal rotation, and hyper-extension are marked. The cause of this condition is obscure. It is observed

that most commonly the condition occurs in rather over-weight and under-sexed young adolescents. This has led to the theory that the epiphysis gives way by virtue of the abnormal weight it is called upon to bear. The presence of rickets or of staphylococcal infection have both been suggested as causes, the former acting by producing a coxa vara deformity of the neck, the angle at which the epiphysis lies on the shaft then being altered so that it easily slips as a result of slight trauma. Injury is an undoubted factor, but an injury sufficient to produce displacement will not do so in a normal hip. In the earliest stages of the disease X-rays will reveal a condensa-

FIG. 243.—EPIPHYSEAL COXA VARA.

Note the marked diminution of the angle between the shaft and the femoral neck on the left side as compared with the normal angle on the right side, accompanied by downward displacement of the epiphysis. There is no destruction or rarefaction of the bone.

tion of the metaphyseal edge of the epiphysis and of the metaphysis. Later the projecting lower edge of the epiphysis is seen spreading outwards apparently along the inferior aspect of the femoral neck. There is separation of the normal line of continuity between the superior aspect of the metaphysis and the epiphysis (Fig. 243). Occasionally in severe cases the head lies absolutely free.

Treatment.—Early cases should be treated by traction in a position of extension, abduction, and internal rotation, this being maintained for a month after reduction has been effected. A walking caliper is then used for a year. Where the symptoms have been present perhaps several months, then open reduction with similar subsequent treat-

ment is required. Later cases where the epiphysis has united to the neck of the femur in a bad position will require osteotomy of the latter bone.

Coxa Valga is the term applied to the opposite deformity, in which the axis of the neck of the femur approaches more to that of the shaft, and the angle of inclination between the two is greater than the normal 125°. It is usually secondary to congenital dislocation or infantile paralysis, and largely due to the absence of the transmission of the body weight. The limb is generally abducted and rotated outwards, and there is some limitation of adduction and internal rotation. The trochanter is flattened and displaced below Nélaton's line. **Treatment,** if necessary, is usually directed to the cause; but if the resulting limp is seriously noticeable, a subtrochanteric osteotomy may be desirable.

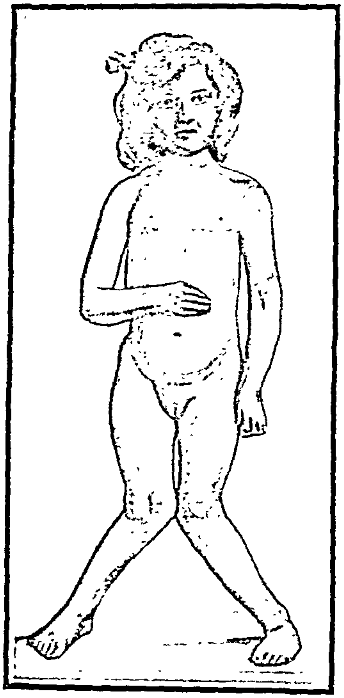


FIG. 244.—GENU VALGUM OF RACHITIC ORIGIN.

The patient was a child aged twelve years. The femora were curved antero-posteriorly, but radiography demonstrated that the trouble in the right leg was as much tibial as femoral in origin. Cuneiform osteotomy of both tibia and femur was needed on the right side, whilst simple osteotomy of the femur sufficed to correct the left side.

A **Clicking Hip** is a troublesome affection in which, when the thigh is moved in certain directions (usually flexion with slight inversion), some deep structure slips over the back of the great trochanter with a snap or crack, and possibly some slight pain. As a rule the structure affected is the tendon of the gluteus medius or the ilio-tibial band of fascia, and most patients are able to carry on their occupations without difficulty, unless called on to undertake heavy walking or severe exercise. Where treatment is necessary, an incision may be made over this hip, for choice under a local anæsthetic, so that the patient may be able to use the joint and demonstrate the actual lesion. The tendon or fascial band thus identified usually requires division and shortening, or re-fixation to the bone in a new position so as to steady it effectively.

Congenital Affections of the knee are mainly connected with the patella, which is sometimes absent, and then other deformities are associated with its non-development. The extensor tendon passes down the front of the knee as a thick band, and the function of the joint is not much impaired.

Congenital Dislocation of the Patella may be present as a persistent lesion, the bone lying to the outer side of the joint ; but more commonly the displacement occurs only at intervals. (See Recurrent Dislocation of Patella, Chapter XXII.).

Genu Valgum, or *knock-knee*, is a deformity in which, if the knees are allowed to touch with the patellæ looking forwards, the malleoli are separated one from the other, *i.e.* it is a condition of fixed abduction of the legs from the middle line, with some external rotation (Fig. 244). One or both limbs may be affected, but if due to general causes the double form is more common. Occasionally genu valgum occurs in one leg, whilst the other is in a condition of genu varum.

There are two main **varieties** of the disease, *viz.*: (1) The rachitic genu valgum of young children, and (2) the static form occurring in adolescents.

The genu valgum of young children arises from the irregular epiphyseal development induced by *rickets*. Increased growth occurs on the inner side of the joint, and this may involve equally the femur and tibia, although most frequently the former is mainly affected. When once the axis of the limb is altered, the weight of the trunk transmitted chiefly through the outer portion of the joint tends to increase the deformity. In not a few cases an antero-lateral rachitic curvature of the diaphysis of the femur is an important element.

The static genu valgum of adolescents occurs most commonly in young children of relaxed constitution, and particularly in those who have to carry heavy weights. Thus, anæmic girls who act as nursemaids and young bricklayers, smiths, and porters, are very liable to it. The method of origin is probably as follows: In the erect posture the femur is normally set at an angle to the tibia (which is vertical) in such a way that the weight of the trunk passes rather through the outer than the inner condyle, whilst the latter structure is lengthened in order to keep the plane of the knee-joint horizontal. This position naturally throws a certain amount of strain and tension on the internal lateral ligament, even in a healthy person (hence its insertion into the shaft and not merely into the upper epiphysis of the tibia); and this strain is increased when the natural position of rest, *i.e.* with the feet separated and slightly abducted, is adopted. A long continuance of this posture tires those muscles on the inner side of the limb which tend to counterbalance this strain, especially if a certain amount of additional weight has to be carried, and particularly in those whose bones have rapidly increased in length and weight without any coincident increase in power of muscles or ligaments. Hence the internal lateral ligament becomes more and more stretched, and not unfrequently a certain amount of lateral mobility of the knee is noticed in the early stages. Subsequently the outer condyle becomes atrophied from more weight being transmitted through it, and the inner condyle becomes lengthened from overgrowth. Flat-foot and lateral curvature of the spine often accompany this form of genu valgum.

Occasionally genu valgum is due to *traumatic causes*, such as fracture of the tibia or femur close to the joint, or lateral dislocation of the knee; whilst, again, it may be caused by atrophy consequent on interference with the epiphysis from local injury or diseases other than rickets. It is sometimes observed, as a result of riding, in those with long legs, as in cavalry soldiers; short-legged individuals, such as jockeys, are more liable to develop a condition of genu varum.

The **Physical Condition** of the parts about the knee may be summarized as follows: (*a*) The inner condyle of the femur is elongated and prominent; the increase in size is mainly in the vertical and transverse directions, and but very little antero-posteriorly, so that, on flexion of the joint, the deformity to a large extent disappears; (*b*) impaired growth and atrophy of the outer femoral condyle and tibial tuberosity are present owing to the weight of the body being transmitted more directly through these structures; (*c*) relaxation of the ligamentous and muscular tissues takes place on the inner side of the joint; this, however, is not constant, especially in the later stages, or in cases which are stationary; (*d*) the tendons and ligaments on the outer aspect of the joint are contracted and shortened, especially the external lateral ligament, the ilio-tibial band, and the tendon of the biceps; (*e*) the patella tends to be thrown outwards, and in bad cases recurring dislocation is sometimes observed; (*f*) in rachitic cases a localized bony outgrowth can often be detected on the inner surface of the tibia about 2 or 3 inches from the joint, and is probably due to a localized periostitis at the point of attachment of the internal lateral ligament.

The feet are displaced outwards, or occasionally inwards, as best suits the convenience of the patient in obtaining as good a footing as possible; the bones of the legs and of the thighs are often bent; and, if the condition is unilateral, scoliosis may result. In well-marked cases the gait of the patient is of a rolling or waddling type, and very characteristic; the legs are partially flexed, and as the condyles touch or overlap they have to be separated at each step to allow of progression.

Treatment.—In *rachitic* cases, the infant requires the adoption of dietetic and therapeutic measures suitable to the condition present. For the local deformity absolute rest in bed is enforced; the limbs are well rubbed daily, and such manipulation and pressure employed as will help to straighten the limb. By perseverance slow but appreciable progress may be made until the deformity is corrected. In older children, splints may be applied on the outer side of the limbs, reaching from the waist or axilla down to the outer malleoli, or, if they are to be kept off their feet, beyond them. These are retained in position by plaster bandages, put on firmly enough to draw the knees outwards. Such an arrangement is often sufficient in early cases to bring about a cure in the course of a few months.

In *static* cases the administration of tonics, such as iron and arsenic, combined with rest, massage, and possibly a change of air, will frequently suffice to determine a cure in the early stages. Suitable apparatus must be adopted when the patient is allowed to walk; that usually employed consists of a walking calliper, jointed at the knee, and fixed below into a slot in the heel of a well-made boot, and attached above to a pelvic band.

When, however, the osseous deformity is fixed, and the patient of such an age as to preclude the hope of a cure by mechanical means, *osteotomy* will be required, and the operation devised by *Macewen*, or some modification of it, is that generally employed. It consists in the division of the femur transversely about a finger's breadth above

the upper border of the external condyle, so as to be well away from the epiphyseal cartilage. Macewen himself used an osteotome* for the purpose, introducing it through an incision made $\frac{1}{2}$ inch in front of the tendon of the adductor magnus, and turning it so as to lie at right angles to the long axis of the shaft; the bone is divided for three-quarters of its diameter, and the remainder is broken. A similar method may be employed from the outer side, the force used in breaking the inner layer of compact bone comminuting and compressing that portion, and so diminishing the deformity. Many surgeons, however, prefer to divide the bone with a saw, previously making a track for it along the front of the femur, and such an operation is certainly simple and efficacious. The limb, having been straightened, is put up at once in plaster of Paris. Union is complete in six weeks, but an immovable apparatus should be kept on for three months.

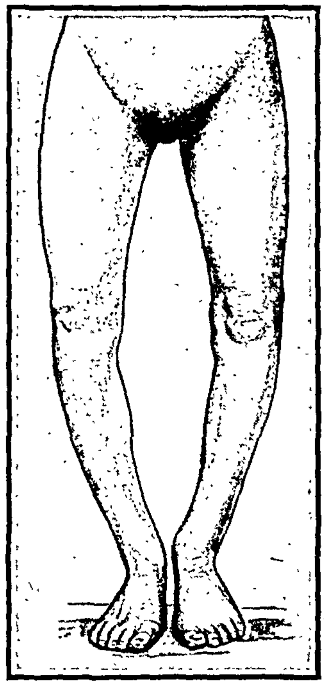


FIG. 245.—BILATERAL GENU VARUM.

The patient was a girl of thirteen years, who had developed this condition during two years, and was the subject of adolescent rickets. Enlargement of the epiphyseal ends of the radius and ulna, and of the costo-chondral junctions, was also present.

Genu Varum is a less common condition, characterized by a fixed separation of the knees when the ankles are in contact (Fig. 245). It arises from three chief causes: (i.) Occupation, and particularly that of a jockey, the short legs being constantly apposed to the sides of the horse; (ii.) traumatism, especially if directed to the femoral condyles; and (iii.) rickets, the lesion usually present being a well-marked excurvation of the femoral shafts, with possibly a similar curve of the tibiæ (*bow-leg*). The condition is usually bilateral and symmetrical, but occasionally one side only is affected, whilst the other leg is in a state of genu valgum. **Treatment** in the early stage is by splints, in the later by operation, which consists either in simple osteotomy above the knee, or in cuneiform osteotomy of the shaft of the femur.

Genu Recurvatum, or *back-knee,* is a deformity occasionally met with, in which the joint is hyper-extended, the limb describing a curve with the concavity forwards; it is necessarily associated with relaxation or stretching of the crucial ligaments, and is usually due to a congenital displacement, possibly the result of the limbs not being flexed *in utero*, but extended with the feet under the chin. It is sometimes the result of paralysis of the extensor muscles, and is then due to the necessity for the patient to keep his knee slightly hyper-extended if it is to be a basis of support;

* An *osteotome* differs from a *chisel* in the fact that the former is bevelled on both sides, whilst the latter is merely bevelled on one side.

in time the posterior ligaments give way, and deformity results. Genu recurvatum may also arise from irregular growth along the epiphyseal line, possibly as a sequela of tuberculous or other disease of limited extent in that region, and sometimes as a result of the disorganization of the joint in Charcot's disease. It has also been known to occur as an acquired accomplishment in fakirs and contortionists. Treatment must be suited to the special requirements of the individual case.

FIG. 246.—RICKETS.

Note the bowing of the bones, the broadening of the diaphyseal extremities, the line of condensation at the lower end of the femoral shaft, and the thickening of the cortex on the concave side of the curved bones. Note also the transverse striations at the lower end of the tibial shaft. These striations, however, are not pathognomonic of healed rickets, but of any disease which has at some time arrested bone growth.

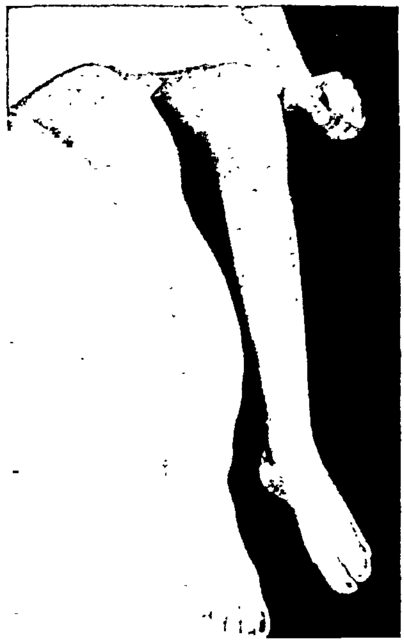


FIG. 247.—RACHITIC DEFORMITY OF BONES OF RIGHT LEG.

Rachitic Deformities of the Bones of the Leg are not unfrequent, if in the course of an attack of rickets a child is allowed to run about. The trouble may involve both segments of the limb, and give rise to a general excurvation, constituting what is known as *bow-legs*, the knees being widely separated the one from the other, and the antero-posterior curve being exaggerated. The femora are bent antero-posteriorly, with the convexity of the curve forwards and outwards; the main convexity of the curve usually occurs about the junction of the upper and middle fourths, and here it may be so marked as to be a cause of spon-

taneous fracture. Cases of this nature may remain under observation for years, where both femora frequently break as a result of extreme rachitic distortion. The *tibia and fibula* (Fig. 246) participate in this deformity, or are separately affected; the antero-posterior curve is usually increased (Fig. 247), and some amount of abduction or adduction may also be present. The bones in these cases are flattened from side to side, presenting a sharp edge in front, with a buttress-like support or strut reaching along the concavity; in time they become exceedingly dense and sclerosed.

Treatment in the early stages consists of rest and constitutional treatment, and in the application of suitable apparatus to reduce the deformity. Where the femora are seriously affected, it may be necessary to provide the patient with an apparatus, *e.g.* a hinged double Thomas's knee-splint, which fits closely round the pelvis, and carries the weight to the ground by lateral metal rods which also maintain continuous extension. In the worst cases operation will be required, but never until all signs of active disease have passed. The bones may be divided at their most prominent parts, or, if necessary, a wedge-shaped portion may be removed (*cuneiform osteotomy*), the sections being made at right angles to the upper and lower segments of the bone respectively. Careful and prolonged after-treatment, including the use of suitable splints, is required, especially where the femora have been divided, in order to prevent a reappearance of the deformity.

The tibia and fibula also become distorted and curved antero-posteriorly as the result of *inherited syphilis*; this usually comes under notice at a later date than the rachitic change, and is due to a deposit of new bone under the periosteum rather than to bending. The deformity is purely antero-posterior, without lateral deviation, whilst the subcutaneous margin of the tibia is rounded, and not sharp as in rickets. Moreover, the curve generally involves the centre of the bone, whilst in rickets the chief deformity occurs either near the knee or a little above the ankle.

Deformities of the Feet.

These cannot be understood properly unless the student grasps clearly the mechanical structure of the foot. It has a twofold purpose: (1) to form a solid and firm basis of support for the body; and (2) to permit of elasticity and spring in the gait. The foot therefore consists of two parts: (1) the solid posterior portion (astragalus and os calcis) through which the weight is transmitted from the leg to the heel; and (2) an anterior segment comprised of the front half of the astragalus and all the remaining bones, set at varying angles (to break up shock), and with movable toes controlled by muscles. Elasticity is also secured by the arches of the foot, which are threefold: (1) The internal longitudinal arch (arch of the instep), which reaches from the heel to the head of the first metatarsal and varies much, but in a well-formed foot is sufficiently pronounced to keep the skin clear of the ground; it is this arch which suffers most in 'flat-foot.' It is maintained chiefly by the inferior calcaneo-scaphoid or 'spring

ligament upon which rests the under side of the head of the astragalus; beneath the ligament passes the tendon of the tibialis posticus, which gives slips to most of the tarsal bones. The long and short plantar ligaments and the short muscles and deep fascia of the foot also assist in maintaining the arch. (2) The external longitudinal arch is of slight importance, inasmuch as the constituent elements (os calcis, cuboïd, fourth and fifth metatarsal) rest almost always on the ground. (3) The transverse arch is the necessary result of the arrangement of the two longitudinal arches extending from the astragalus to the heads of the metatarsal bones, and varies in its degree with the height of the instep; should this be lost, the transverse arch must obviously disappear. It is chiefly maintained by the peroneus longus tendon.

Talipes.

By talipes, or club-foot, is meant a deformity of the foot due to muscular, ligamentous, or osseous causes, the displacement occurring mainly at the ankle and mid-tarsal joints; it may be either congenital or acquired.

The *congenital* variety is often hereditary, and may be found in several members of the same family; it is sometimes associated with other deformities, such as hare-lip and spina bifida. It may arise from malformation of some of the bones of the foot, or of the lower end of the tibia or fibula; but probably it is more commonly due to malposition of the feet *in utero* induced by an unusually small uterine cavity or a deficient amount of liquor amnii, as a result of which the feet are abnormally compressed and held in one position.

The *acquired* varieties arise from some derangement of the equilibrium normally maintained between opposing groups of muscles, in consequence of which the more powerful group draws the foot into an abnormal position. Thus it may be due to: (*a*) *Paralysis*, the result of infantile palsy, or of peripheral nerve lesions; (*b*) *cicatricial* contraction of muscles from diffuse suppuration. Thus penetrating wounds, followed by suppuration of the gastrocnemius or soleus, often cause such a degree of cicatricial contraction as to constitute a talipes equinus, whilst necrosis or caries of the tibia may lead to such changes in the tibialis anticus or posticus as to determine a position of talipes varus. (*c*) Essential muscular shrinking, resulting from a chronic myositis fibrosa, is occasionally met with in elderly people. (*d*) It also occurs in *spastic* paralysis (p. 531). (*e*) Shortening of the leg from hip or knee mischief often induces a *compensatory* talipes equinus, whilst injuries or diseases of one of the epiphyses of the leg bones may stop its growth, and then the continued development of the other bone forces the foot to one side or the other. (*f*) Finally, prolonged maintenance of the foot in a bad position may lead to permanent deformity, as in the variety known as talipes decubitus.

Four primary forms of talipes are described, *viz.*: **T. Equinus,** in which the heel is drawn up, the patient walking on the toes (plantar flexion); **T. Calcaneus,** in which the toes are raised from the ground (dorsiflexion); **T. Varus,** in which the anterior half of the foot is adducted and inverted, and the inner side of the foot is raised, the patient

walking on the outer; and **T. Valgus,** due to abduction and eversion of the anterior half of the foot, or to yielding of the longitudinal arch on the inner side. Not unfrequently mixed forms occur, due to the association of two of the above, *e.g.* T. equino-varus, or T. equino-valgus, or T. calcaneo-valgus.

As to the *relative frequency* of these different forms, there is not the slightest question that T. equino-varus is by far the commonest. If, however, we exclude congenital cases and flat-foot, T. equinus is in all probability the variety most frequently observed.

Talipes Equinus (Fig. 248, A, B, and C) is almost always acquired; as a congenital lesion it is very uncommon. It is a very frequent sequela of gunshot wounds of the muscles of the calf, which have been followed by suppuration or required partial excision for gas gangrene; cicatrization naturally draws up the heel and brings about this deformity. It also occurs as a compensatory manifestation where the limb has been shortened, as after hip disease, and may follow the prolonged pressure of bed-clothes on the dorsum of the foot of a bed-ridden patient (T. decubitus). The paralytic form is the result of any lesion of the nerve-fibres which control the anterior tibial group of muscles, and if these are divided above the anterior tibial nerve the peronei muscles are also likely to be involved, and the deformity has an element of varus added to the 'drop-foot' which follows. When resulting from poliomyelitis, the muscular involvement may be a little less regular in its distribution. In both of these conditions the equinus deformity is of the flaccid type.

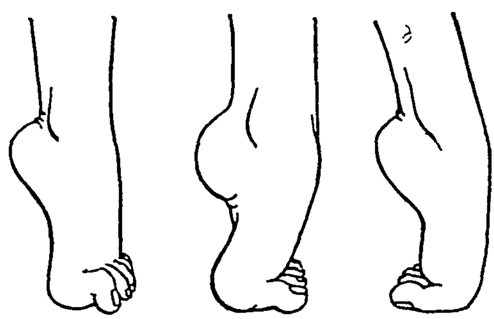


Fig. 248.—Various Forms of Talipes Equinus.

In the slightest cases all that is noticed is that the foot cannot be dorsiflexed beyond a right angle (right-angled contraction of the ankle). When more marked, the heel is drawn up, and the patient walks on the heads of the metatarsal bones and on the toes, which are usually hyper-extended, but may occasionally become flexed (Fig. 248, C), so that in time the whole dorsum of the foot may even be turned downwards.

Secondary changes occur in old-standing cases. The astragalus is displaced forwards from under the malleolar arch, only the posterior part of the articular surface being in contact with the tibia. In the paralytic type the anterior segment of the foot drops at the mid-tarsal joint, so that the head of the astragalus and scaphoid constitute a marked prominence beneath the skin. In all cases the sole of the foot is liable to be shortened by contraction of the plantar fascia and of the short plantar muscles (pes cavus), and a certain amount of varus is frequently present. In this, as in all forms of talipes, callosities, and perhaps bursæ beneath them, form over points of pressure, *viz.* under the heads of *all* the metatarsal bones.

Talipes Varus, or, as it is most frequently termed, **Equino-varus,**

is the commonest variety of congenital club-foot, and is then often bilateral, and may be accompanied by other congenital defects, *e.g.* hare-lip or spina bifida. As an acquired deformity, T. varus is not a very unusual result of infantile palsy affecting the extensor and peroneal muscles, although the equinus element usually predominates; other cases are due to a spastic contraction of these muscles.

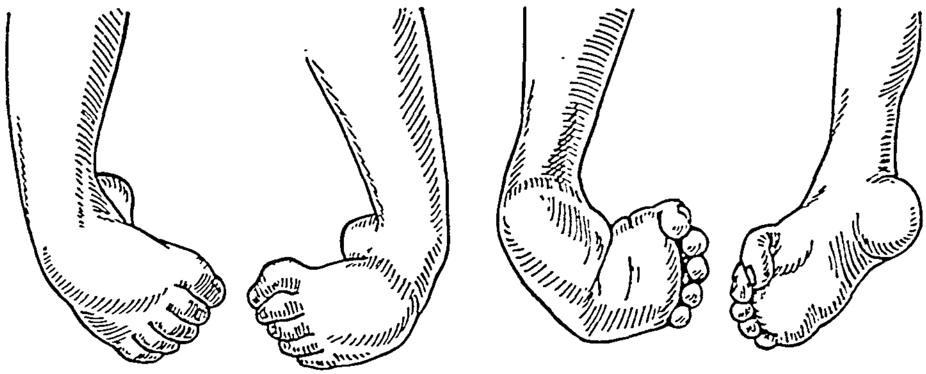


FIG. 249.—DOUBLE TALIPES EQUINO-VARUS OF CONGENITAL ORIGIN SEEN FROM IN FRONT AND BEHIND.

The heel is drawn up, and the anterior half of the foot adducted and drawn inwards (Fig. 249). The inner border of the foot is concave, and a well-marked transverse crease crosses the sole on a level with the mid-tarsal joint; the outer border is convex, and in adults

FIG. 250.—CONGENITAL TALIPES VARUS OF MANY YEARS' DURATION.
The large bursæ on the outer sides of the feet induced by walking are very noticeable.

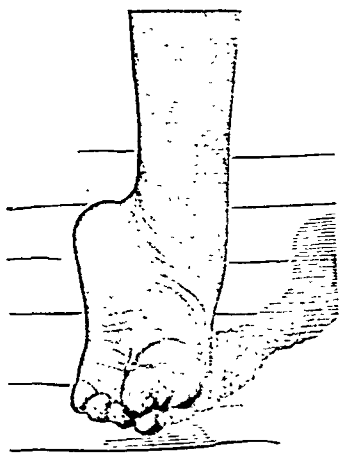


FIG. 251.—VERY NEGLECTED CASE OF TALIPES VARUS.

who have walked a thick bursal formation is usually present over the cuboid (Fig. 250). In neglected cases the patient may even stand on the dorsal aspect of the latter bone (Fig. 251). The sole of the foot is arched from secondary contraction of the plantar fascia and short muscles of the sole, and a longitudinal crease may run down the centre of the sole, owing to doubling over of the outer metatarsal bones.

The most marked *anatomical changes* in the congenital type are found in the astragalus, the neck of which is elongated and inclined inwards; the bone also projects forwards from under the tibio-fibular arch, the posterior portion of the upper articular facet alone remaining in contact with it. The scaphoid is displaced to the inner side of the head of the astragalus, and its tubercle is usually in close proximity to, or may even touch, the inner malleolus. The os calcis and other tarsal bones are also modified in position and shape to correspond with these changes. The dorsal tendons are displaced inwards, usually occupying the centre of the concavity between the foot and the leg. The ligaments on the inner side of the foot are contracted, especially the anterior portion of the deltoid, the inferior calcaneo-scaphoid, and to a less extent the long and short plantar ligaments.

The following table indicates the chief diagnostic points between congenital and paralytic T. equino-varus:

	Congenital.	*Paralytic.*
History	Affection has existed from birth.	Affection not developed till the second or third year, and ushered in by convulsions, fever, etc.
Feet affected	Usually bilateral.	More often unilateral.
Circulation	Good.	Feeble; limb is sometimes cold, blue, and clammy.
Muscles	But little wasting	Extreme wasting.
Electrical Reactions	Not much impaired.	Almost entirely absent in paralyzed muscles.
Growth of Bones	Much as usual.	Considerably diminished.
Creases in Sole	Present.	Absent.

Talipes Calcaneus is an unfrequent variety of the deformity, and may be either congenital or acquired. In the *congenital* form (Fig. 252) the toes are drawn upwards so that the heel alone comes into contact with the ground, the sole pointing forwards. The extensor tendons are contracted, but the toes may be flexed owing to the tension of the flexor longus digitorum. It is sometimes associated with deviation of the foot inwards or outwards, constituting a condition of T. calcaneo-varus or valgus. The *acquired* variety (Fig. 253) is generally due to infantile palsy of the calf muscles, or occasionally to overstretching of the tendo Achillis after tenotomy. The longitudinal arch of the foot is increased (pes cavus), partly from the development of a large pad of fat over the calcaneal tuberosities, but mainly from the dropping of the anterior half of the foot from the mid-tarsal joint.

Talipes Valgus is a condition seldom met with as a *congenital* deformity, except in association with T. equinus. In it the foot is abducted and everted, owing to contraction of the peronei muscles. The sole becomes flattened, and the inner border of the foot comes in contact with the ground (Fig. 254). Considerable pain is usually experienced after walking a short distance. This deformity is occasionally due to absence of the fibula. The *acquired* variety, which is not uncommon (Fig. 255), results from paralysis of the tibial muscles, or from spastic contraction of the peronei, the condition in these cases closely simulating flat-foot.

The **Diagnosis** of the different varieties of talipes is, as a rule, easily made, although the cause of the deformity is not always so readily ascertained. In *paralytic* cases the limb is generally atrophied, bluish in colour, and feels cold and clammy. Trophic lesions are not uncommon in the form of recurrent ulceration, and even ulcers of the perforating type may develop, especially in cases due to peripheral

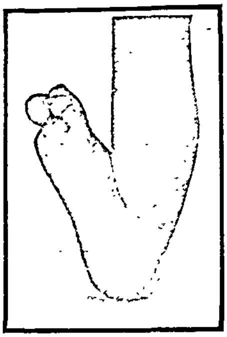


FIG. 252.—CONGENITAL TALIPES CALCANEUS.

FIG. 253.—PARALYTIC TALIPES CALCANEUS WITH WELL-MARKED HALLUX FLEXUS.

nerve lesions. The trouble is often unilateral, and the muscles are wasted and flabby. In *congenital* cases the condition is usually symmetrical, and of course present from birth; considerable resistance is felt on any attempt being made to correct the deformity, and the limbs look healthy, are well nourished, at any rate at first, and free from trophic lesions. In *spastic* cases (most frequently T. equinus)

FIG. 254.—TALIPES VALGUS (CONGENITAL), WITH A LITTLE TENDENCY TO CALCANEUS.

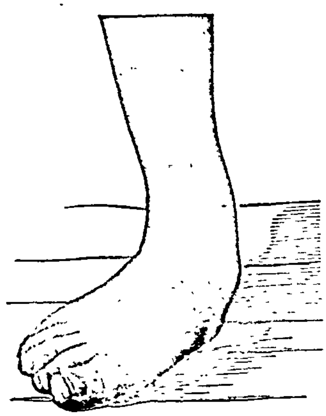


FIG. 255.—PARALYTIC TALIPES VALGUS.

spasm or contraction of other parts is usually present, which renders the diagnosis obvious; one or both limbs may be affected; the reflexes are exaggerated; the gait is characteristic; and the muscles, at first simply contracted, may finally atrophy.

The **Treatment** of talipes is always tedious, demanding care and

patience on the part of all concerned. It is important to discriminate accurately between the different varieties, and to recognize the actual anatomical lesions present in each.

Talipes equinus, if secondary to hip disease, should not, as a rule, be interfered with. When likely to develop as a result of intrinsic muscular contraction (post-suppurative or otherwise), it may be prevented by keeping the foot at right angles by a suitable splint, or in plaster of Paris. When fully developed, tenotomy of the tendo Achillis (p. 472) may be required, accompanied if necessary by division of the plantar fascia, whilst in neglected cases, or where tenotomy has failed, excision of the astragalus gives excellent results, the patient being able to walk subsequently with a plantigrade foot.

In the *paralytic* variety, whether central or peripheral, every effort must be made to conserve and render more efficient all muscular tissue that is capable of functioning, and thus massage and electricity are required and the adoption of a satisfactory position. In old-standing helpless cases of *drop-foot* with flaccid muscles and relaxed joints, operations to stabilize the foot must be considered, and a subastragaloid arthrodesis seems to be the most satisfactory means of securing this. The ankle-joint itself is not stiffened, but the patient wears an external iron, and thereby stability is secured. Other surgeons prefer Whitman's operation, which consists in removing the astragalus through an incision on the outer side of the foot. The foot is then displaced slightly backwards, and the malleoli fitted into suitable beds prepared on the inner side in front of the sustentaculum tali, and on the outer by gouging out a hole in the os calcis or cuboid. When healed, a considerable degree of stability is secured, and with the aid of a surgical boot walking is possible.

Congenital T. equino-varus.—As already indicated, treatment should be commenced as soon after birth as possible, and the intelligent co-operation of both mother and nurse must be secured. Two or three times a day the infant's foot must be firmly manipulated into as good a position as possible and held there for some minutes. The surgeon will undertake the same once or twice a week with a little more energy. The object aimed at must be clearly appreciated, *viz.* firstly, to overcome the cavus element, then to abduct and evert the foot, and finally to remedy the equinus position.

When the child is from three to six months old, it is possible to apply a plaster retentive dressing, and hence if by that time simple manipulation has not succeeded in overcoming the deformity, a definite attempt must be made under an anæsthetic to correct it, but only by manipulation. The foot is then put up in plaster with the knee at a right angle, the plaster reaching to the mid-thigh with changes for movements once in two weeks. In most children under twelve months of age this treatment is successful, though in a few division of the tendo Achillis may be required.

If the case is very resistant or is not brought to the surgeon till later (one to three years), when bony growth tends to fix the deformity, it may be necessary to attempt *forcible correction* under a general anæsthetic by the employment of Thomas's wrench (Fig. 259), applied

over a suitable packing of wool. Failing this, subcutaneous or open division of the anterior portion of the deltoid or internal lateral ligament of the ankle may be required, as also of part of the inferior calcaneo-scaphoid ligament; the tibialis anticus and posticus tendons may also need division. Subcutaneous elongation of the tendo Achillis is the final step of the corrective operative treatment, but it must be noted that this is not necessarily all undertaken at one sitting. Plaster of Paris cases are applied until the foot remains in a good position without pressure, and then a metal malleable splint or tin night-shoe (Fig. 256) is applied. Massage and passive movements are required, and later on education in walking.

When the child does not come under observation until the deformity is fixed, and still more when the foot has been used in its bad position for walking, operations directed to the bones will be required. In the less severe cases, division of the neck of the astragalus may be undertaken from the dorsal aspect, and the os calcis can be divided just behind the calcaneo-cuboid joint, together with such section of tendons and ligaments as may be required. In the worst cases, however, *cuneiform tarsectomy* or removal of a wedge-shaped portion of the tarsus, with its base outwards, and regardless of exact anatomical details, must be performed. This is accomplished through a semilunar incision on the outer side of the foot; the thick subcutaneous structures, including the bursa, are removed, and the extensor tendons, already somewhat displaced inwards, are stripped from the bones and held aside. The tarsus is divided by a chisel in two places so as to include a wedge with its base outwards; the lines of section are as far as is possible at right angles to the anterior and posterior segments of the foot, and sufficient bone is taken away to permit the foot to come into good position without difficulty. After closing the wound an ordinary removable splint is applied at first until the wound is healed, and then a plaster case is employed for six or eight weeks. The results are excellent, the foot, although a little shortened, being firm and plantigrade.

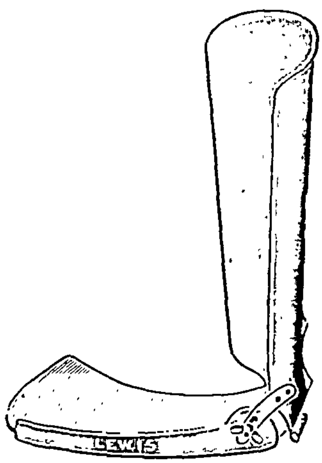


FIG. 256.—TIN NIGHT-SHOE USEFUL IN CASES OF TALIPES WITH MOVEMENTS POSSIBLE IN VARIOUS DIRECTIONS.

In *paralytic T. varus* of central origin, with persistent paralysis of the peronei muscles, it will often suffice to transplant the healthy active tendon of the tibialis anticus from the inner side of the foot to the outer, implanting it in the cuboid, to which it is firmly sutured with the foot everted and dorsiflexed; it is maintained in this position by means of plaster of Paris for six weeks. If this is not sufficient, Whitman's operation (p. 517) must be used, and leg-irons provided.

In congenital *Talipes calcaneus* all that may be needed is division or lengthening of the extensor tendons; but in the paralytic variety some form of apparatus must always be worn. Where the tendo

Achillis is thin and attenuated, a portion of it may be excised, and the ends united by suture; or the tubercle of the os calcis into which the latter is inserted may be sawn off and re-attached by a nail or peg to the bone at a lower level; but the prognosis in all forms due to paralysis is unsatisfactory.

Talipes valgus must be treated along the same lines as a flat-foot (*q.v.*). If unrelieved by the application of suitable boots, division of the peroneal tendons may be required, or in severer cases wrenching the foot into position, and fixation in plaster of Paris. Removal of a wedge-shaped portion of bone from the inner aspect of the foot may be undertaken, but is not very successful.

Flat-foot (*syn.:* **Splay-foot** or **Spurious Valgus**) is a condition frequently seen in young adults whose occupation exposes them to over-fatigue, or the carrying of heavy weights, *e.g.* in nurse-girls, shop-boys, and in young recruits. It occurs as a natural condition in many of the negro races, and is more often seen in long than in short feet. It is also not uncommon in women about middle life, especially if called on unexpectedly to take over heavy domestic duties.

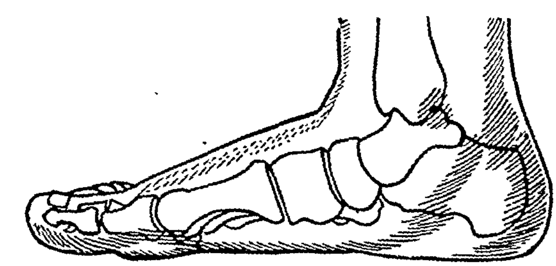


FIG. 257.—FLAT-FOOT.

Mechanism.—In the majority of cases it is due to relaxation of the structures which keep up the longitudinal arch of the foot, especially of the inferior calcaneo-scaphoid or 'spring' ligament, upon which rests the head of the astragalus. A rapid increase in the length and weight of the skeleton apart from an equivalent increase in strength of muscles and ligaments throws undue strain upon this structure, especially if the patient is suddenly exposed to long hours of standing or weight-carrying. The ligament stretches, the head of the astragalus sinks, the anterior portion of the foot becomes abducted at the mid-tarsal joint, and the typical splay-foot results. The tibialis posticus is often relaxed or even paretic, and the peronei tendons are in the later stages contracted, but in some cases spasm of the peronei muscles is apparently the primary cause of the deformity. Occasionally it is due to a gonorrhœal or septic inflammation of the inferior calcaneo-scaphoid ligament, which becomes relaxed and yields under the weight of the body. In a few cases it results from grosser traumatism, *e.g.* fracture of the neck of the astragalus, or of the sustentaculum tali, or it may follow a badly treated Pott's fracture. Care must be taken to differentiate flat-foot with tenderness on the inner side of the arch from Köhler's disease due to subacute osteitis of the scaphoid (p. 646); radiographic examination is here helpful.

However produced, the *deformity*, when fully established, is tolerably characteristic (Fig. 257). The sole of the foot is flat, and in well-marked cases comes in contact with the ground throughout the whole of its extent, as indicated by a print of the sole (Fig. 258). The inner

border is convex and somewhat lengthened, whilst the anterior half is everted and abducted. The head of the astragalus is felt a little in front of and below the internal malleolus, whilst the sustentaculum tali, which is normally distinguishable about ¾ inch below the malleolus, is buried by this displacement. The tubercle of the scaphoid is less evident than usual, being situated below and in front of the head of the astragalus.

In the early stages the foot may appear to be normal or merely a little everted when the patient puts no weight on it; but when he stands, the sinking of the arch becomes evident, and increased pain is produced. As the condition progresses, the front of the foot is more and more displaced outwards, and the astragalus sinks into the sole. After a time inflammatory troubles are lighted up in the joints, and adhesions form in and around them; or the deformity may become fixed by bony changes. In the early or first stage, therefore, the patient himself or the surgeon can easily restore the foot to a normal position; in the second stage, it may be possible for the surgeon to do so, but probably only under an anæsthetic; finally, in the third stage, when ankylosis has occurred, it is impossible to restore the arch apart from operation.

FIG. 258.—FOOTPRINTS OF HEALTHY (LEFT) AND FLAT FOOT.

The raised arch of the instep in the healthy foot is represented by the hollow on the mesial side; when the arch is exaggerated (T. cavus), this hollow becomes more distinct, and may actually divide the print into two. In flat-foot it entirely disappears.

The subjective symptoms are pain and a sense of weakness and fatigue, especially about the origin of the tibialis muscles, at first only experienced after or during exercise, but subsequently persistent. In the more acute cases, pain is complained of in the sole, and especially below and behind the tubercle of the scaphoid in the situation of the 'spring' ligament; this may be very pronounced before the arch has actually given way. Later, when the bony displacement is becoming more marked, pain across the dorsum is complained of over the astragalo-scaphoid joint; and when the displacement is still more severe, pain on the outer side of the heel may become prominent, probably owing to the outer malleolus impinging on the os calcis. In not a few cases, however, there is but little pain when the arch has totally collapsed. Flat-foot is not unfrequently associated with hallux rigidus (p. 523), and this may be extremely painful.

Treatment.—In the first stage, all that is required in the majority of cases is rest in bed for a few days if the 'spring' ligament is very tender, together with massage; by this means overstrained ligaments and muscles recover themselves. Tonics may also be administered to improve the general health. If the condition is of gradual onset, it may not be necessary to confine the patient to bed. The most

important element in the treatment is the provision of suitable *boots*, which shall assist in keeping the foot inverted and thrown slightly over on to its outer border. The boots should be low-heeled and square-toed, and the inner borders should be straight; the heel must be thickened upon the inner side $\frac{1}{3}$ inch, tapering off to the outer side, and carried forward under the arch for $\frac{3}{4}$ inch further than is usual; a patch $\frac{1}{3}$ inch thick should also be placed on the inner side of the sole. All boots, shoes, and slippers must be similarly treated, and the patients in bad cases must *never* be allowed to put foot to ground without this support; a few minutes on his feet without support may undo the good work of weeks. The patient must be taught to walk with his toes straight in front of him, and with no trace of eversion. Tiptoe exercises with the feet inverted are useful in strengthening the short muscles of the sole, as also massage and electricity. The latter may advisably be employed in the form of galvanic foot-baths, followed after a time by the use of the faradic current. The feet are placed in a shallow bath of warm water, which should just reach the instep. The electrodes are arranged so that the current passing between them

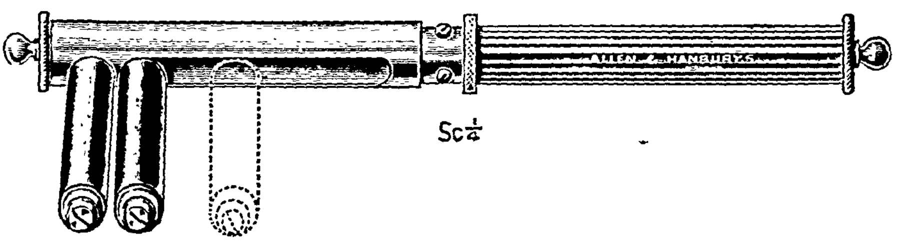


FIG. 259.—THOMAS'S WRENCH.

The two cross-bars are protected by thick indiarubber, and can be approximated or separated by rotation of the handle. The anterior portion of the foot is firmly grasped between them, one being placed on the dorsal and one on the plantar aspect, and forcible wrenching movements can then be carried out.

traverses the longitudinal muscles of the sole. The anterior part of the transverse arch can also be treated by passing the current through the foot from side to side at the level of the metatarso-phalangeal joints.

When the affection has reached a later stage, and the deformity cannot be remedied by ordinary manipulation, forcible rectification under an anæsthetic may be employed. The foot is firmly grasped in the two hands or in a Thomas's wrench (Fig. 259), and the anterior portion is forced inwards and backwards in such a way as to draw the scaphoid round the head of the astragalus as a fulcrum, and thus restore the arch. Probably a number of adhesions in the astragalo-scaphoid and other joints will be felt to give way during this manipulation. Tenotomy of the peronei is sometimes required before rectification of the position is possible. The foot is put in plaster of Paris and kept at rest for some weeks, and then boots are supplied, and graduated exercise allowed. Satisfactory results have followed.

When the deformity cannot be rectified even by wrenching, and weight-bearing is still a source of pain, the patient may be advised

to wear a carefully-fitted instep pad (fitted to a plaster cast of the foot) to assist in supporting the weight; but it must be clearly understood that this contrivance should never be employed for cases where a cure can be established along the lines laid down above. In mid-life these supports are sometimes extremely useful.

In a few cases with a fixed deformity operative proceedings directed to the bones may be justified. The removal of a wedge-shaped section from the inner side of the foot, and the production of bony ankylosis between the scaphoid and astragalus, is the only operative procedure worthy of consideration. Prolonged rest and a suitable course of exercises and massage will be required subsequently, whilst an instep pad may still have to be worn.

Loss of the Transverse Metatarsal Arch is a frequent cause of sore feet when walking, and may accompany either pes planus or pes cavus, and is often associated with hammer-toes and hallux valgus. It is due largely to loss of power of the peroneus longus, but a good many other elements enter into its causation. It is characterized by the heads of the metatarsals sinking so as to be brought into contact with the ground, and as a result callosities form under them which are extremely painful. It is often possible to press up the metatarsals into a normal position and to retain them there by pressure applied transversely around the foot just above the heads, and this can be utilized in **Treatment.** A strip of chamois leather can be made to surround the foot in the position indicated and held there by strapping; or, better, an elastic band 2 inches wide can be worn around the foot with or without a pad of rubber placed centrally in the sole; with this can be combined an elastic loop which will serve to keep the big toe in correct alinement. Boots with bars across the sole as in Fig. 260 are also most helpful, relieving the pressure on the painful metatarsal heads. Only when measures such as these fail need the operations mentioned in the section on pes cavus be considered.

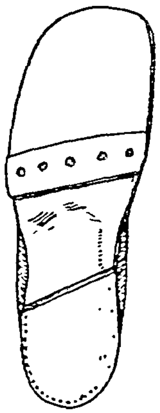


FIG. 260. — BOOT WITH CROSS-BAR ON SOLE FOR USE IN PES CAVUS.

Pes Cavus (Hollow or Claw Foot) is a condition characterized by increased concavity of the plantar arch, so that when the individual stands there is a greater interspace than usual, if not an absolute break, between the impressions produced by the anterior and posterior segments of the foot (Fig. 248, B). Corresponding to the plantar concavity there is a marked dorsal convexity, whilst the toes are generally in a condition to be immediately described as hammer-toe; the heads of the metatarsal bones are unduly prominent below, and callosities often form beneath them, causing considerable pain. The condition is almost always associated with a slight degree of talipes equinus (right-angled contraction), and its method of production from this cause is said to be as follows: The weight is normally carried to the ground mainly through the heel, but also partly through the toes; in these cases it is only transmitted through the toes and front of the

foot, and since the anterior extensor muscles are probably weak, the short flexors act at an advantage, and by contracting draw the heel downwards so as to reach the ground, and thus the arch is increased.

In the later stages the foot becomes inverted and assumes a varus deformity; the toes become blue, contracted and painful, and walking becomes almost impossible.

Treatment.—In the early stages, when the deformity is slight and easily replaceable, the Achilles tendon should be divided or lengthened (pp. 472 and 473), and the foot put up in plaster in a position of dorsiflexion. When walking is permitted, the boot must have low heels, and a bar should be placed obliquely across the sole so as to rest just behind the heads of the metatarsals (Fig. 260); the object of this is to maintain dorsiflexion, and throw the body weight on the heel more than on the toes.

In the next stage the heads of the metatarsals begin to project in the sole and become tender. If only the first metatarsal is involved, the trouble may be remedied by detaching the tendon of the extensor proprius hallucis, drilling a hole transversely through the head of the metatarsal, and threading the tendon through it, finally fixing its divided end to the tendon above so as to constitute a loop which lifts the head of the bone. The plantar fascia will also need division, and perhaps the tendo Achillis, so that the foot can be put up in plaster of Paris in dorsiflexion. Subsequently, boots are supplied as indicated above.

Hallux Rigidus (*syn.:* **H. flexus**) is a painful condition of the great toe, due to a chronic arthritis of its metatarso-phalangeal articulation. It usually occurs in young males with flat feet. The foot is abnormally long; its circulation is defective; the toe itself may be in good position, but not unfrequently the first phalanx is flexed and the distal one hyperextended. The condition is probably due to abnormal pressure owing to the valgoid position of the foot, and possibly to wearing too short a boot. It sometimes arises as a result of direct trauma, *e.g.* a weight falling on the toe, or being 'run over.' **Treatment.**—In the early stages correct the flat-foot, and see that suitable boots are worn. A transverse bar behind the heads of the metatarsals (Fig. 260) is sometimes useful. Careful strapping with Scott's dressing may also give relief. In bad cases where bony changes have occurred (lipping, etc., as in osteo-arthritis), excision of the head of the metatarsal may be required.

Hallux Valgus (Fig. 261) consists of a displacement outwards of the great toe from the median line of the body, as a result of which the other toes are huddled together, and in extreme cases the hallux is placed over or under them. It is present in the majority of people in some measure, owing to the usual shape in which boots are made; but in its severer forms it is due to a chronic arthritis of the metatarso-phalangeal joint, the greater power of the abductor group of muscles explaining the deformity. The cartilaginous surface of the head of the first metatarsal bone becomes inflamed owing to the partial dislocation of the toe and the pressure of the boot; its structure and shape are thereby altered, and the joint is more or less disorganized.

Two other conditions are often associated with this deformity, *viz.* bunion and hammer-toe.

A *bunion* consists in the formation of a bursa over the head of the first metatarsal bone, which becomes inflamed from cold or injury, and may even suppurate, the abscess often communicating with the joint, and leading to its disorganization. A marked bony outgrowth is usually found under the bursa, springing from the inner side of the head of the bone, and due to a localized periostitis.

The **Treatment** of hallux valgus in its earliest stages consists in the use of correctly-shaped boots, with the inner border straight from toe to heel, whilst the sock or stocking should have a separate compartment for the great toe. The introduction of a toe-post between the great toe and its neighbour is sometimes effective in giving relief. A boot with a cross-bar across the sole (Fig. 260) is also useful by relieving pressure on the heads of the metatarsals. In more severe types excision of the projecting head of the metatarsal bone gives admirable results. The operation is best conducted by turning up a flap of skin and subcutaneous tissues over the inner aspect of the head of the metatarsal with its convexity forwards. The bone is then exposed by splitting the internal lateral ligament and transversely divided by a chisel; the head is removed completely, allowing the toe to be easily replaced in a normal position. The skin is then laid down in place and if need be shortened to meet the requirements of the case. This operation is better than merely removing a wedge from the neck of the bone, or chiselling off the projecting bony overgrowth. The toe should be maintained in a good position by the dressing, and massage is commenced early. A good movable joint results, though the toe is slightly shortened. Care must be taken subsequently to see that suitable boots are worn. Very rarely ought the second toe to be removed for this condition, as the lateral support of the great toe is thus weakened, and the deformity is probably aggravated. An *inflamed bunion* is treated by removing all local pressure, and applying fomentations. If the joint is involved in suppurative disease, excision of the head of the bone, or amputation of the toe, may be required. In less serious cases it may suffice merely to remove the thickened bursa and to chisel away the projecting portion of the bone.

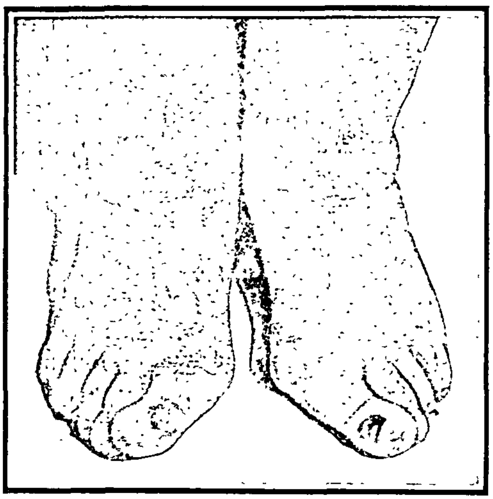


FIG. 261.—BILATERAL HALLUX VALGUS WITH BUNIONS.

Hammer-Toe.—This deformity is constituted by hyper-extension of the first phalanx, marked flexion to an acute angle of the second, and either flexion or extension of the terminal phalanx, so that the first

interphalangeal joint projects under the upper leather of the boot, whilst the patient walks on the extremity of the ungual phalanx, or even on the nail. Callosities form upon the points of pressure (Fig. 262, 1, 2, and 3), especially on the dorsal aspect, and a subcutaneous bursa over the head of the first phalanx (4), giving rise to great pain and inconvenience. The second toe is that most frequently affected, with or without the others, but it is uncommon for the hallux to be thus deformed. The extensor tendons often stand out very evidently beneath the skin. The flexion of the second phalanx on the first is often carried to such a degree that the former bone is semi-dislocated. The prolongations of the plantar fascia on either side are much shortened, and the lower portions of the lateral ligaments of these articulations are also contracted.

Causes.—It is occasionally congenital, but more often acquired, and then (*a*) it may be secondary to hallux valgus; (*b*) it may result from wearing short and pointed boots, or very high heels; in either case the toes are crowded together and drawn up out of the way of pressure; (*c*) it follows contraction of the plantar fascia, and is then associated with pes cavus and talipes equinus.

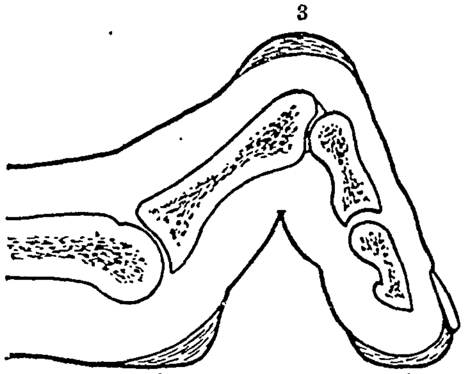


FIG. 262.—HAMMER-TOE.

1, Callosity over head of metatarsal bone in sole; 2, callosity over end of toe; 3, callosity or corn over head of first phalanx.

Treatment may be commenced by the use of correctly-shaped boots, but the case has usually progressed to such an extent when the patient is first seen that no palliative measures are of any avail. Operation is then necessary, and probably the second phalanx is so much displaced that nothing short of removal of the head of the first phalanx holds out any prospect of permanent relief. An incision is made longitudinally over the joint, the extensor tendon being split down the middle; the head of the bone is then cleared by the raspatory, and nipped off by cutting pliers. No splint is required, as the pressure of the dressing suffices to keep the toes in good position. Sometimes there is but little room between the great and third toes, so that even if one corrected the deformity of the second toe there is no space for it to lie comfortably; amputation should then be performed.

Metatarsalgia, or **Morton's Disease,** is characterized by severe pain of a neuralgic type located primarily about the head of one or more of the metatarsal bones, usually the fourth, but also radiating thence up and down the limb. It often occurs in gouty or rheumatic subjects, and may be attributed to some injury; a slight degree of flat-foot and the wearing of tight boots certainly predispose to it. It is probably due to compression of the digital nerves between the heads of the metatarsal bones and the ground. The foot is found to be broader than

usual, and the anterior transverse arch formed by the heads of the metatarsals flattened out. Marked callosities, or corns, are observed on the under surface close to the heads of the bones, one or more of which may be unduly prominent below. In a few cases small bony enlargements have projected from the heads of the metatarsal bones, and in some definite fibrous growths have been found in the subcutaneous tissues; in other cases a simple peripheral neuritis may explain the manifestations. The pain is generally induced by walking, and comes on in characteristic paroxysms. Lateral pressure over the bases of the metatarsal bones often relieves the pain, but similar pressure over the heads usually increases it. Occasionally evidences of osteo-arthritis are manifested in one of the neighbouring joints.

Treatment consists in resting the foot, whilst suitable diet and drugs are ordered to combat any gouty or rheumatic tendency. At the end of a few weeks the patient may be allowed to walk again with boots which are low-heeled, thick-soled, and broad anteriorly, with an obliquely set bar behind the heads of the metatarsal bones (Fig. 260). Associated deformities of the foot are dealt with appropriately, and the callosities on the sole by suitable chiropodical methods. Morton's recommendation, *viz.* excision of the head of the projecting metatarsal bones, may be reserved for the more aggravated and serious forms; it is best effected through a longitudinal dorsal incision running parallel to the extensor tendons.

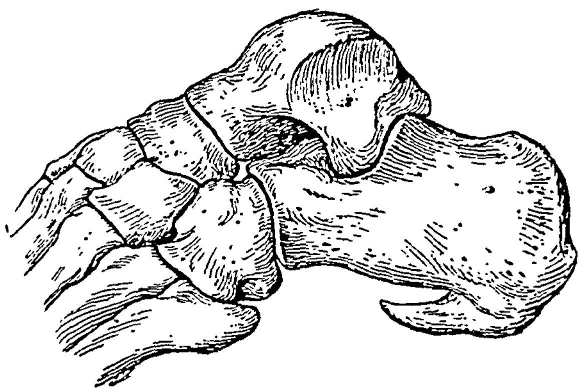


FIG. 263.—BONY SPUR BENEATH OS CALCIS. (DRAWN FROM SKIAGRAM.)

Painful Heels.—Patients are not unfrequently seen who complain of disabling pain about the heel in spite of careful attention to the fit of boots. This may be the result of not a few various causes, and careful discrimination is necessary to make a correct diagnosis.

1. If the pain is purely plantar, it may be due to a gouty deposit in the deep fascia or muscles, and merely requires constitutional treatment. If, however, this is unlikely, an X-ray examination will sometimes reveal the existence of a bony spur (Fig. 263) from the under side of the os calcis, due to ossification of the attachment of the deep fascia and resulting probably from strain. Operation in these cases is essential in order to excise the spur and any adventitious bursa that may have formed over it. One need hardly say that the incision should be placed posteriorly (horseshoe-shaped) or laterally, and not in the sole.

2. If the pain is posterior, it is probably due to inflammation of the bursa beneath the tendo Achillis, or to periostitis beneath the insertion of that structure, resulting from strain. If rest is of no

avail, igni-puncture may be useful, or the newly-formed bone may even require to be excised.

3. If the pain is deeper and more central, it is possibly due to injury of the bony cancelli in the os calcis, resulting from a fall or blow on the heel and some secondary osteitis or periostitis. This must be treated on general principles, but it is often very intractable.

The terms 'infantile paralysis' and 'spastic paralysis' have been employed so frequently during this chapter as having important ætiological relationships to deformities that it appears desirable to add here a short description of these affections.

Infantile Paralysis.

This condition, by far the most common cause of paralysis in children, is due to an acute infective inflammation of the anterior horns of the spinal cord (*acute anterior poliomyelitis*), resulting in destruction of the multipolar ganglion cells without suppuration, and followed rapidly by paralysis and degeneration of the muscles supplied from that area.

The causative organisms have not yet been actually isolated, inasmuch as they are apparently ultra-microscopic and pass through a filter. Portions of an infected cord inoculated into monkeys produce the disease, and the cell-free fluid obtained after crushing up such cord débris and filtering, even through coarse porcelain, is similarly effective. The virus remains active in a dried cord for some weeks.

Infection apparently commences in the naso-pharynx, and then spreads up the olfactory nerves, causing first a meningeal reaction, and subsequently an invasion of the nervous tissue itself, either of the brain or of the cord, but more frequently of the latter. The condition of the cerebro-spinal fluid in the acute stage before paralysis has occurred is quite diagnostic: it is under pressure; the albumen content is increased; there is an excess of cells (polymorphs or lymphocytes) with normal sugar and normal chlorides, and no organisms can be cultivated from it; there seems, however, no relation between the number or character of the cells and the type or gravity of the case.

The disease mainly affects children between two and five years of age, but it is not uncommon throughout childhood, and even occurs in adults. The incubation period varies, but in many cases does not exceed three or four days. Infection commences in the naso-pharynx, and hence in schools and other institutions there should be sufficient room in the dormitories to prevent the children from coughing in one another's faces; beds may be arranged alternately head to feet with advantage. The disease is often transmitted by carriers who are themselves immune.

In England and in the United States of America anterior poliomyelitis is a notifiable disease, for although it is not usually very common, yet occasionally serious outbreaks occur. It is seen much more frequently in the tropics, and many grave epidemics have been reported in various parts of the world, *e.g.* the New England states of America and New Zealand. In this country it shows a seasonal

variation, three-quarters of the cases developing between June and October.

The **course** of the disease is best described in three stages:

1. The inflammatory **stage of onset** often starts abruptly, and is ushered in by a short febrile attack with severe pain in the head and neck, perhaps extending to the spine; the head is retracted and fixed by muscular spasm, and there is often some hyperæsthesia of the body. This stage may persist for some days and be followed by one of paralysis, or the condition may abort, possibly as the happy result of a spinal puncture for diagnostic purposes. The symptoms are obviously due to the initial meningeal reaction. The paralysis comes on suddenly and rapidly reaches its maximum, within perhaps a few hours, and any change thereafter lies in the direction of improvement. The affected limb is helpless and relaxed, the muscles are completely paralyzed and undergo rapid atrophy; reflexes disappear, as also electric excitability, although the reaction of degeneration may often manifest itself. The affected limbs are cold and bluish in colour. The disease is rarely generalized, but its *distribution* is very variable, mainly involving the limbs, and that in any type of combination. In the arms the deltoid is most commonly affected, less often the biceps, brachialis anticus, and supinator longus; occasionally the extensors of the wrist and fingers are paralyzed. The legs are much more frequently attacked than the arms, and the lower rather than the upper halves; the tibialis anticus and extensors are involved more often than their opponents. In the thigh the quadriceps and adductors bear the brunt of the trouble. The spinal muscles participate in the disease occasionally, but the face and sphincters are not affected.

The inflammatory condition, as indicated by pain and fever, lasts perhaps for six weeks, and is followed by—

2. The **reparative stage,** during which the mischief in the cord is being made good as far as possible by the development of cicatricial tissue, and such ganglion cells as have escaped destruction are beginning to regain their power of control over the muscles dependent on them. This may occur at any time after the passing of the acute stage, and may progress slowly or rapidly, and only after the completion of this period can an assured judgment be formed as to the actual extent of the mischief. A period of two years or more is often occupied in this stage, and during its course deformities are liable to develop, growth is checked, and trophic manifestations may appear. Response to galvanic stimuli is the first indication of repair, and so long as the reaction of degeneration exists, one need never give up hope of improvement; then comes response to faradic excitation, and finally voluntary movement.

3. The **stationary period** is at length reached, when a final opinion may be formed as to the extent of the mischief, and arrangements made for assisting the patient by operative or other treatment, which must not be considered so long as improvement in muscle tonus is occurring. Henceforth, the surgeon's aim is to protect the damaged and weakened limbs from injury, to guide growth along right lines, and to assist impaired function, whilst at the same time provision

must be made for the education and amusement of the child with a view to making him ultimately an independent member of the community.

Prognosis, therefore, is most difficult in the earlier stages. No one can tell exactly how much damage has been done in the cord, or how that damage will influence the limbs in the direction of ultimate paralysis or cessation of growth. A prolonged first stage is often a precursor of delayed repair and a protracted recovery. Extensive paralysis does not necessarily connote inefficient growth, which may appear with very slight muscular impairment. Fairly complete early

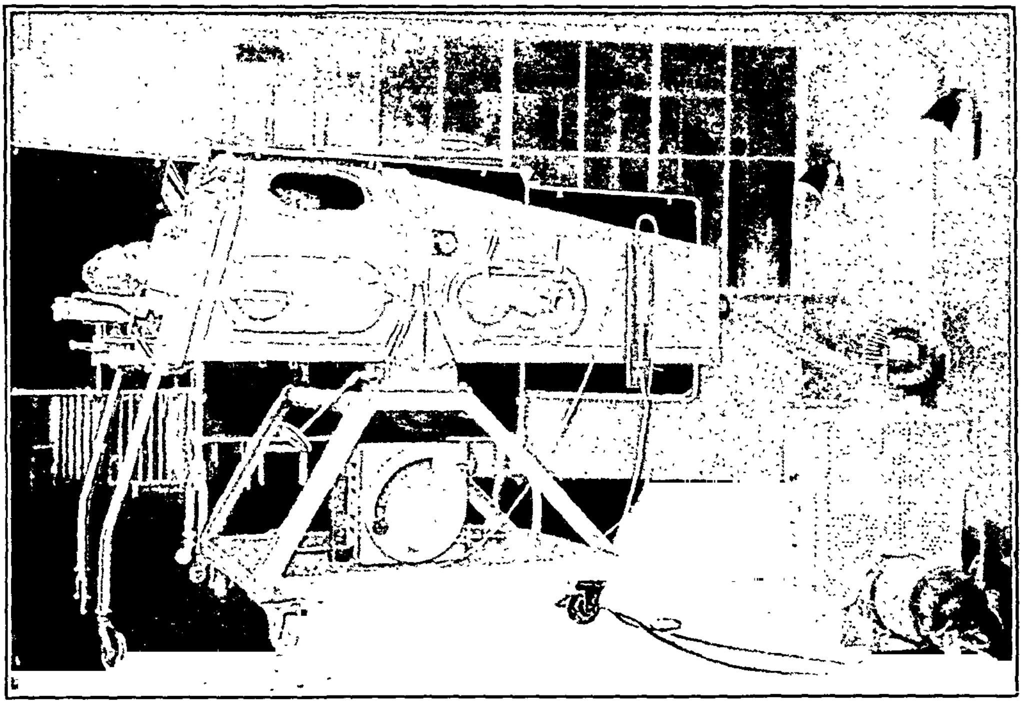


FIG. 264.—DRINKER'S APPARATUS.
The child had paralysis of the respiratory muscles.
(Sir Henry Gauvain.)

paralysis of both lower extremities usually carries with it a bad outlook, especially if persisting after three months.

Treatment necessarily varies with the stage of the disease, and the practitioner must keep clearly in mind the objects to be attained in each.

In the **first stage** the prime essential is rest and quiet, so that the inflamed and damaged cord may be put in the best condition for checking the destructive process and limiting the mischief caused thereby. The whole body must be immobilized as far as possible in a Thomas's double spinal frame or some such contrivance, and wrapped in cotton-wool to protect it from peripheral stimuli. The feet are placed at right angles to the legs, and maintained thus by

splints or plaster applied over thick cotton-wool. The relative position of the thighs to the pelvis must also be watched. Local applications of heat or cold, electricity or massage, are alike harmful in this stage. Should the paralysis of the diaphragm occur the child can be kept alive in a Drinker's apparatus (Fig. 264) and the paralysis of the diaphragm will recover.

In the **second stage** the chief efforts of the practitioner must be directed towards the prevention of deformities, the correction of any that have developed, and the restoration of muscular power and function. Careful study of the case is necessary, in order to determine the electrical condition of individual muscles, which should be carefully charted for future reference.

The *prevention of deformity* is governed by the fact that a paralyzed muscle is always liable to become stretched under the influence of gravity or of opposing muscles, so that even if contractility is in time restored, the over-stretched muscle cannot fulfil its function. All paralyzed muscles must be kept relaxed until recovery occurs, and this applies as much to times when treatment is being undertaken as to periods of rest; massage and electricity must be employed with the affected muscles in a position of relaxation. Splints and postural treatment are also required during this period in order to maintain a correct position. With a paralyzed deltoid, the arm must be kept abducted; for paralysis of the flexors of the forearm, the elbow must be bent to a right angle; for paralytic drop-foot, a position of dorsi-flexion must be maintained. All splints during this stage must be light and of a simple nature. As the muscles regain tone and power, a certain limited range of movement is permitted, and gradually increased inch by inch; but the power of the muscle must not be over-taxed, or it will lose rather than gain ground.

The *correction of deformities* is often required owing to neglect in the early stages, and is governed by the principles just enunciated. If muscular re-education and electrical stimulation cannot effect this, appliances to maintain a correct position must be employed, or even operative treatment.

Massage is of the greatest value in the restoration of muscular tone, if applied intelligently. Its object is to stimulate and develop the weakened muscles, and that without undue fatigue. At first gentle friction is alone required, but later the deeper parts can be kneaded. When the time comes for active exercise of the muscles, they must be called into contraction at first without allowing the weight of the limb to exert its influence. *Electrical treatment*, too, must be judicious, or it may be of little value. The immersion of a limb in an electric bath is calculated to exercise the strong rather than the weak muscles, and the retention of the limb in the correct posture under these circumstances is difficult or impossible. Interrupted galvanic stimulation to the individual muscles is the best form to employ until sufficient repair has occurred to permit of response to faradic stimuli, and then this variety may be utilized. Over-fatigue of the muscles must not be permitted. However, active exercises in a warm bath may be very beneficial.

In the third or **chronic stage** the surgeon's chief object is to restore the patient's usefulness, so far as is possible, by correcting deformities and stabilizing weak and flail-like limbs. *Mechanical appliances* are often needed, but must be carefully devised in order to assist, and not to hamper movement by unnecessary weight. Celluloid, papier-mâché, or some such material may be utilized for the simpler cases, whilst for metal contrivances duralumin may sometimes take the place of steel. In paralytic talipes equinus irons fixed to the boots and rising above the knees, or even sometimes running up to the pelvis, are frequently required.

Operative measures are directed towards either the restoration of the muscular balance or to the fixation of a flail joint. (*a*) Division of tendons or fasciæ is seldom desirable in paralytic cases; the muscles of the limbs are already sufficiently weakened. However, in paralytic drop-foot, contraction of a healthy tendo Achillis is sometimes so great that the foot cannot be restored to its correct position by passive movement, and then it must be lengthened; shortening of over-stretched paralyzed muscles is seldom of much use. (*b*) *Tenoplasty* (p. 473), or grafting the tendon of a healthy muscle into a paralyzed one, has a certain limited scope in this affection, but requires the most precise recognition of the value and utility of the muscles employed. (*c*) *Tendon fixation* (p. 475) is of some value as a means of stabilizing a flail limb, *e.g.* in paralytic drop-foot, but unless the tendons are fixed very near to the articular surfaces, and only short lengths employed as accessory ligaments, they are extremely likely to stretch subsequently. (*d*) *Arthrodesis*, or the fixation of joints, is a useful proceeding when the unnatural mobility is difficult to control, or would necessitate considerable addition to the weight of any apparatus required, or where from the poverty of the patient such apparatus cannot be obtained. It is especially serviceable in cases where two joints in a limb are flail-like, one of which may be ankylosed with advantage. The operation consists in a modified excision, the cartilage alone being sawn or scraped from the ends of the bones, but it must always be remembered that the reparative activity in a paralyzed limb is small. It is usually unnecessary in the hip-joint; it is decidedly valuable for the flail knees of older children, where the expense of apparatus has to be considered. A stiff ankle is undesirable, but arthrodesis of the astragalo-calcanean joint is useful if suitable tendon operations can be arranged to steady the ankle. (*e*) Where the whole limb is hopelessly powerless and an inconvenience to the patient, *amputation* is often the best practice. In the lower extremity, when the knee and ankle are both weak and flail-like, arthrodesis of the knee and removal of the foot by a Syme's amputation will often provide the patient with a serviceable limb.

Spastic Paralysis (*Syn.*: Little's Disease, Cerebral Diplegia, etc.).

Under this title are included a group of cases in which the characteristic feature is spasm of various groups of muscles, leading in time to a fixed deformity, and weakness or paralysis of other muscles,

possibly the opponents of the above. The cause is always some permanent defect of the upper motor neurons, which not only impairs the passage of excito-motor impulses, but also hampers the conduction of inhibitory impulses from cortex to spinal centre. The result of this is that peripheral stimuli reaching the centres from below have an undue power of producing reflex activity, and hence, in such conditions as the cerebral diplegia of children, spastic contraction of muscles is induced, and the mere placing of the foot on the ground in the attempt to walk produces such spastic contortions as to render progress difficult, if not impossible.

A certain degree of spasticity occurs in various diseases of the central nervous system in *adults*, *e.g.* after hemiplegia (but preceded in this case by a period of flaccid paralysis), in disseminated sclerosis, etc.; but it is not necessary to discuss these.

In *children* spastic paralysis may be due to localized polio-encephalitis, cortical thrombosis (post-exanthematous), or syphilitic disease; but in the great majority of cases it is a birth palsy, probably resulting from punctiform hæmorrhages in the cortex of pons, occurring during birth from undue moulding of the bones of the skull or from asphyxia, and this in spite of the story of a normal labour, which is usually forthcoming.

The affection may appear as a hemiplegia, diplegia, paraplegia, or monoplegia, the two former being the more common and occurring in the proportion of 9 : 7. The characteristic contractures are as follows:

In the lower extremity, spastic equinus, due to inefficiently controlled plantar flexion of the foot; flexion of the knee and adduction of the thigh, combined sometimes with internal rotation.

In the upper extremity, pronation of the forearm and flexion of the wrist.

(*a*) At first the contractions can be overcome and the limb straightened, although the mere attempt to do so often induces spasmodic action of the muscles, which, however, can be banished by deep anæsthesia. In time the contracted muscles become actually shortened, and restoration to the normal position is impossible. (*b*) The actual loss of muscular power in the opposing group varies much in degree, but is always present, and must be taken into account in considering operative treatment; this applies particularly to the arm lesions. (*c*) Mental deficiency to a greater or less degree is commonly present in these patients; in hemiplegia 68 per cent. are subnormal, and in cerebral diplegia 84 per cent. The mentality of every patient should be carefully considered before undertaking a course of treatment which requires the co-operation of the patient for its successful completion. (*d*) Involuntary movements of an athetotic type are often evident in these cases, and will seriously hamper all attempts at treatment.

Treatment.—Massage and electricity to the muscles, however devotedly applied, are useless in effecting a cure, and can never be of much use; operative treatment can alone be expected to be of any lasting benefit.

Stoffel's operation consists in division of a sufficient number of the

motor fibres leading to the spasmodic muscles to restore the balance of control, and to render them more on a level with the weakened group of opposing muscles. This theory has been substantiated in practice to a great extent. Spasmodic equinus is dealt with by dividing a half or two-thirds of the nerve tracts to the gastrocnemius and soleus, but this must sometimes be accompanied by local treatment to lengthen the tendo Achillis. Flexion contracture of the knee requires division of a sufficiency of the nerve-fibres leading to the hamstring muscles, but older cases also need tenotomy of these muscles. Adductor spasm is treated by division of branches of the obturator nerve. For pronation and flexion of the forearm and wrist, the nerves to the pronators and flexors may be attacked, but the results are not very favourable, owing to the degree of weakness usually present in the opposing groups; it may be wiser in such cases to employ these muscles by transplanting them so as to strengthen the weak supinators and extensors of the wrist and fingers, in the same way as they are used in old musculo-spiral paralysis (p. 414).

The actual method of division of the nerve-fibres varies somewhat; Stoffel's original suggestion was to deal with the main trunks, depending upon the knowledge now available as to the arrangement of the fibres in these trunks; other surgeons divide the peripheral nerves close to the muscles, although this involves a much more extensive dissection.

Re-educational exercises must be instituted as soon after the operation as is considered safe, and here the question of the patient's mentality arises. Considering the unpromising material on which the work has to be done, the results have been most encouraging, but it is obvious that unless the patients are brought under observation early, the prognosis is likely to be unfavourable.

CHAPTER XX.

INJURIES OF BONES—FRACTURES.

Contusion of a Bone and of its periosteum is usually a matter of no great moment, although the part becomes painfu land swollen. Occasionally a subacute periostitis is caused in people liable to rheumatism or gout, or in the subjects of syphilis; whilst in those with low germicidal power acute infective osteomyelitis, resulting in necrosis, may supervene. If the periosteum is torn, osteogenetic cells may be set free from its under-surface and escape into overlying muscles, leading to new bone formation therein (traumatic myositis ossificans, p. 466). **Treatment** consists in rest and the use of cooling lotions or of a bandage, whilst if periosteal thickening results, iodide of potassium may be given, and iodine paint applied locally.

Bending of Bone may or may not be associated with fracture. Bending without fracture occurs mainly in children, and in adults is only the result of some local disease. More commonly a partial or green-stick fracture is produced (p. 536), and in this the deformity can generally be corrected without much difficulty.

Fractures.

A fracture may be defined as a sudden solution of continuity in a bone, usually resulting from external violence.

Predisposing Causes of Fracture—*Age.*—From two to four fractures are not uncommon, owing to the unsteady gait and frequent falls to which little children are liable; from four to six the bones often bend so as to cause green-stick fractures; up to the age of eighteen years injuries near joints induce separation of epiphyses; from six years onwards fractures increase in frequency, reaching their maximum between thirty and forty years of age; old people are liable to this form of accident, owing to the bones becoming atrophic or brittle.

Sex.—As might be expected, fractures are more common in the male sex during boyhood and adult life; but up to the age of four or five they are equally frequent in the two sexes, whilst after forty-five they are more common in women, owing to their great liability to fracture of the cervix femoris and to Colles's fracture.

Morbid Conditions of the Bones predispose in a marked manner to what is known as *Spontaneous Fracture*, in which the determining force cannot be recognized or is very slight. Under this heading may be included: (1) Atrophy of bone, which may be of the senile type, as manifested especially in the cervix femoris; or is due to want of use, as in a paralyzed limb or from an ankylosed joint. (2) Patients afflicted with certain mental or nervous diseases, such as general

paralysis or tabes dorsalis, are unduly liable to fracture, which may occur in apparently healthy bones. A man, for instance, suffering from tabes was sitting with his thigh abducted and everted in order that he might examine and dress a perforating ulcer on the sole of the foot, when the shaft of the femur, subsequently shown to be of normal dimensions, and apparently of normal density, snapped in two. (3) Osteogenesis imperfecta (Chapter XXI.) consists in an inherited tendency to spontaneous fracture. Thus, a girl, aged twelve and a half years, had suffered from forty-one fractures since the second year of life. (4) General bone diseases, such as rickets and osteomalacia, also predispose to fracture; in the latter affection the bones often bend considerably before breaking. (5) Local bone disease, such as sarcoma and secondary cancer, may also be first recognized by causing a spontaneous fracture; the erosion of an aneurism and the destruction of the para-epiphyseal region in acute osteomyelitis may lead to a similar result.

The **Exciting Causes of Fracture** are threefold: (1) *Direct violence*, the fracture occurring at the spot struck, and being often transverse, not unfrequently comminuted, and sometimes complicated with injuries to the adjacent soft parts. (2) When due to *indirect violence*, the accident is usually produced by the compression or bending of the bone with such force as to exceed the limits of its natural elasticity, so that it yields at the weakest spot. Thus, when a person jumps from a height, the leg bones are compressed between the weight of the body and the resistance of the ground, and, if the violence is excessive, a fracture occurs at some point of mechanical disadvantage. If the stress falls chiefly on the shaft, an oblique fracture ensues, often with much longitudinal displacement, and possibly becoming compound; if an element of torsion is present, as by forced inversion or eversion of the foot, the fracture is likely to become spiral in type. If, on the other hand, the violence expends itself on a mass of cancellous tissue, such as the os calcis, astragalus, or upper end of the tibia, the bone may be fissured in various directions, comminuted, or even 'pulped'; such a condition is sometimes termed a *compression fracture*. (3) *Muscular action* is most commonly the cause of fracture of small bones or of osseous prominences, into which powerful muscles are inserted. The patella and olecranon are not unfrequently broken in this way, the former often occurring from sudden and vigorous efforts to avert a fall. Occasionally one of the long bones, such as the humerus or clavicle, has been broken by violent muscular exertion, as by throwing a cricket-ball.

Intra-uterine Fractures are caused by blows upon the mother's abdomen, or by abnormal or violent uterine contractions, especially if the liquor amnii is deficient in amount or if the formation of bone is defective, as in osteogenesis imperfecta; they are usually followed by considerable deformity. **Obstetric Fractures** occur during delivery, usually affecting the shaft of the femur or humerus.

Varieties.—A **Closed (Simple) Fracture** is one in which the skin is unbroken, or, at any rate, where the external air has no admission to the site of injury. An **Open (Compound) Fracture** is present when

the skin or mucous membrane is so lacerated that there is direct or indirect communication between the fracture and the external air. In the base of the skull, a fracture may involve one of the deeper air-sinuses, and thus becomes compound without any apparent external lesion.

Fractures are complete or incomplete, according to whether or not the continuity of the bone is entirely interrupted. Various forms of **Incomplete Fracture** are described, and indeed the introduction of radiography has shown that they are much more common than was formerly supposed. A *green-stick fracture* (Figs. 265 and 266) is one which only occurs in young children, and most often in those that are rickety; curved bones, such as the clavicle, are most frequently affected, and the fracture merely involves the convexity of the curve, whilst the concave half is bent, just as when a green bough or twig

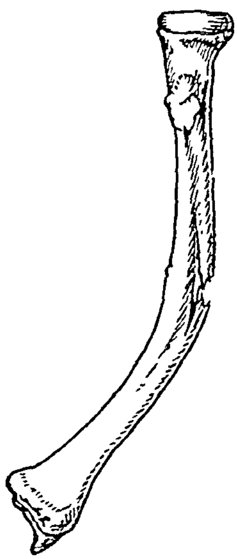


Fig. 265.—Green-stick Fracture of Radius.

Fig. 266.—Green-stick Fracture of Radius and Ulna.

is partially broken. *Depressions* of the skull may be similarly incomplete when the outer table is driven in without fracture and the inner table alone splintered. *Fissured fractures* also are often only partial. A *subperiosteal fracture* is one in which the periosteum remains intact, although the bone is broken; displacement does not occur, and therefore the injury is likely to be overlooked, apart from radiography.

Complete Fractures may be *transverse*, if due to direct violence; *oblique*, arising usually from indirect violence; *spiral*, when the force acts in a rotary direction as well as longitudinally; it occurs most frequently in the tibia or femur, and the lower fragment often has

a sharp triangular upper end, giving it somewhat the appearance of the mouthpiece of a clarionet (fracture *en bec de flute*). Not uncommonly a second fissure runs downwards from the main line of fracture, separating off a long narrow fragment of the shaft. A *longitudinal* fracture is one due to fissuring or splitting of the bone in its long axis; it is most common as the result of gunshot injuries. If it is combined with a transverse fissure, it is often termed T-shaped. *Comminuted* is a term used to describe the condition when the bone is broken into more than two pieces; *impacted*, when one fragment is driven into the other; *multiple*, when more than one fracture exists; *complicated*, when important structures such as an artery, nerve, or joint, are damaged as well as the bone.

The **Separation of an Epiphysis** results in young people from violence directed to the ends of the bones, but occasionally from pathological affections of the epiphysis or of the adjacent portion of the diaphysis, *e.g.* from inherited syphilis, rickets, scurvy, acute osteomyelitis, or tuberculous disease. The femur, humerus, or radius are the bones most often affected. The line of cleavage usually runs through the soft spongy tissue on the diaphyseal side of the cartilage, so that there is cartilage with spicules of bone on one side and spongy bone on the other. In very young children, where the epiphysis is entirely or mainly cartilaginous, the lesion is almost always a pure separation of the epiphysis from the shaft; but at a later date it not unusually extends in part through the adjacent end of the diaphysis (Fig. 267). A marked feature is the stripping up of the periosteum, which, though loosely attached to the shaft and easily separated from it in children, is firmly adherent to the epiphyseal cartilage, and hence retains its connection with it, thus frequently limiting displacement. If, however, the force is sufficient, the end of the shaft penetrates the periosteum, which grasps it closely, and this periosteal 'sleeve' often hinders reduction. Union usually occurs by means of bone, but arrest of the longitudinal growth may follow if the parts are not replaced in exact apposition. This is a matter of importance when one of the bones of the leg or forearm is affected, since deformity of the hand or foot results if the injured bone ceases to grow and the uninjured one continues its development. Suppuration sometimes follows in unhealthy children, or when the accident is compound, and may result in acute osteomyelitis.

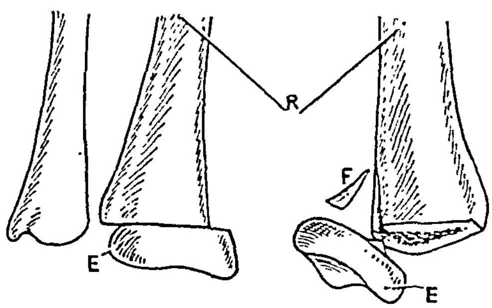


FIG. 267.—SEPARATION OF LOWER EPIPHYSIS OF THE RADIUS, DRAWN FROM AN X-RAY FILM.

E, Epiphysis; R, radius; F, small fragment of bone from diaphysis.

Partial detachment of an epiphysis (the *juxta-epiphyseal strain* of Ollier) often occurs, giving rise to phenomena similar to those of a sprain; if neglected, it may interfere with the growth of the limb.

The essential feature is a more or less tender, but very distinct, swelling of the bone close to the epiphysis, but the neighbouring joint remains unaffected. Treatment consists in immobilization in plaster of Paris.

Signs of Fracture.—The history usually given by the patient is that, as the result of some accident, he felt, or perhaps heard, something give way with a snap, and experienced sharp pain which became much intensified on attempting to move the limb. On examining the injured part and contrasting it with the opposite side, the following points are usually noticed:

1. The *signs of a local trauma, viz.* pain, bruising, and swelling, as a result of the effusion of blood from the torn and lacerated structures. The amount of this may be so great as to obliterate all the ordinary bony prominences and landmarks. Blebs and bullæ sometimes appear over the surface after a day or two, and must be carefully protected from infection. The discoloration may spread by gravity to parts far removed from the original mischief. This infiltration often leads to considerable subsequent thickening, and possibly to adhesions and limitation of movement. It is unusual for suppuration to occur after a closed fracture, unless the patient is very debilitated and with diminished germicidal powers.

2. *Preternatural mobility in the continuity of the bone* may be demonstrated by manipulation, but never unnecessarily. Impaction or non-separation of the fragments prevents its occurrence.

3. Partial or complete *loss of function* also follows.

4. *Crepitus** can only be felt when the fragments are movable and can be brought into contact, but not when there is wide separation, complete overlapping, or impaction.

5. Change in shape of the limb or *deformity from displacement* results from three chief factors, *viz.* the direction of the violence, the weight of the limb, and the contraction of muscles, whilst injudicious movement or rough handling may aggravate it. It is always more marked in oblique than in transverse fractures, and hence is usually greater in those due to indirect violence. Various types of displacement are described, *viz.*: *Angular*, generally due to the unequal action of powerful muscles; *lateral*, where the displacement is merely to one or the other side, and most common in transverse fractures; *longitudinal*, when one fragment overlaps the other or is forcibly driven into it, causing shortening of the limb; it may also occur in the form of wide separation of the fragments, as from contraction of the quadriceps in fracture of the patella; *rotatory*, when one fragment is twisted on the other, as in fractures of the femur, where the weight

* The term *Crepitus* is applied to five different conditions which may produce a creaking or grating sensation to the examining hand. (1) *Bony* crepitus results from the rubbing together of the fragments in a fracture, or of the ends of bones in a joint when denuded of their articular cartilage. (2) A softer variety of bony crepitus is obtained when an *epiphysis* is detached. (3) An effusion of *blood* into the tissues gives rise to a soft crackling sensation on handling. (4) *Effusion* into tendon sheaths, bursæ, and joints also causes a soft crepitant sensation, varying in different cases. (5) *Air* in the tissues causes surgical emphysema and a characteristic form of crepitus.

of the limb causes eversion of the lower end. In flat bones, *e.g.* the skull, deformity may exist in the shape of *depression* or *elevation.*

Radiography has proved of the greatest service in connection with both the diagnosis and the treatment of fractures. Many a case which would formerly have been called merely a sprain can now be demonstrated to be really a fracture (especially about the wrist and ankle), and its constant use has revolutionized our ideas as to the relative frequency and nature of many such lesions. Indeed, there is at the present time too great a tendency to rely on radiography for diagnosis, to the detriment or loss of that delicate tactile sensation which surgeons of old days had to acquire. The diagnosis of most fractures *can* be made without the use of radiography; its employment should be looked on as confirmatory, and only diagnostic in difficult cases. It is most important, however, that the result of 'putting up' the fracture should be tested by radiography, as thereby defects of alinement may be recognized and early corrected.

A satisfactory diagnosis can never be made with the screen alone; the limb must be photographed, and for choice stereoscopically; otherwise, the skiagram should be taken in two directions. The importance of this is indicated by a study of Figs. 298 and 299, p. 592. It must also be remembered that all skiagrams are more or less exaggerations, varying with the proximity of the tube to the limb, and thus a deformity which is very obvious in the radiograph may in reality be comparatively slight. Finally, one must not forget that callus is for a considerable time pervious to the X-rays, so that, although the fracture is firmly united, it may be still apparent in the skiagram.

General or Constitutional Effects.—*Shock* is great or less according to the character of the violence, the seat of injury, and the amount of pain caused by the accident and its treatment.

Hæmorrhage is rarely sufficient to give rise to general effects unless the fracture is open, and involves some important vessel.

Fracture Fever (aseptic traumatic fever) is met with in the majority of cases, commencing twenty-four hours after the accident and lasting two or three days. As a rule it is not severe, the temperature rarely rising above 100° F. in uncomplicated cases. In open fractures where asepsis has not been attained, any variety of wound infection may result, and even general septicæmia or pyæmia.

Traumatic Delirium.—Although delirium is merely a symptom, it is occasionally of so pronounced a character as to demand special attention. Three forms are described:

(*a*) The *Active Delirium* which accompanies severe injuries, particularly in plethoric, and often in previously healthy individuals, whose environment has been suddenly changed from that of everyday life to a sick-bed in a hospital ward. Infection of the wound is usually present, and the delirium runs a course parallel with the fever. It is not usually of a violent type, although the patient may be irrational and restless; he moves the injured part without any evident appreciation of the pain which, if conscious, he must suffer, but he is easily restrained by the exhibition of firmness and tact on

the part of the attendant. The symptoms are most marked at night, and commence at the end of forty-eight hours, lasting, as a rule, for two or three days. There is a distaste for food, which, however, can be overcome by gentle persuasion.

Treatment.—Patients in this condition must never be left; the diet should be light, but nourishing; the bowels are thoroughly opened, and an icebag to the head may be useful. The wound should be freed from any purulent accumulation.

(*b*) *Delirium of a Low Muttering Type* is met with in individuals of low vitality, exhausted by dissipation, drink, disease, or faulty hygienic surroundings. It is commonly associated with fever of an asthenic type, such as is seen towards the end of infective diseases. The patient usually lies on his back, staring vacantly upwards, is incoherent, takes no notice of surrounding objects, and is observed to pick at the bedclothes and mutter to himself unintelligently. There is often, in addition, an involuntary escape of urine or fæces. The mouth is generally open, the tongue dry, brown and cracked, and viscid mucus collects about the teeth (*sordes*).

The **Treatment** should be directed to careful nursing and feeding, as by that means alone can the patient be saved.

(*c*) **Delirium Tremens** is observed in individuals who, previously of intemperate habits, have suffered some serious injury, such as a compound fracture. The violent symptoms do not set in till about the third day, but are usually preceded by some amount of sleeplessness and wandering at night, or the patient may have short snatches of sleep, from which he awakes semi-delirious. This gradually increases, and is followed by violent delirium, in which the patient is haunted by terrifying visions of reptiles, horrible insects, and the like, from which he tries in vain to escape. During this stage of excitement he is with difficulty restrained from jumping out of bed; in many instances these patients are remarkably cunning, and, managing to elude the vigilance of their attendants, will succeed in escaping from the room by the door or window, and may inflict serious, and even fatal, injuries upon themselves or others. There is always a tremulous condition of the extremities and of the tongue, which is white and coated, whilst the bowels are obstinately confined. The pulse and temperature vary considerably, and the skin is often moist and clammy. The violent stage is always followed by profound exhaustion, in which the patient may gradually sink into a state of coma and die. In the case of a fractured leg, the struggles of the patient will cause considerable displacement of the limb, and necessitate constant attention to prevent further mischief. The limb should never be fixed to the bed, but slung in a Thomas's splint, or immobilized in plaster of Paris.

Treatment.—When fractures are treated in patients in the habit of taking alcohol regularly, it is important to see that the regular intake is not suddenly stopped. Such sudden alteration in the daily routine may precipitate an attack of delirium tremens. In cases where an attack is considered imminent, either from the previous history of the patient, the tremulous state of his hands and tongue, or his sleep-

lessness, the best treatment to adopt is to support the strength by suitable easily digested food, combined with free purging and, if need be, soporifics, such as chloral, bromide, paraldehyde, or morphia. Paraldehyde is perhaps the safest, whilst morphia must be administered cautiously; under such a regimen the symptoms usually soon disappear. In the acute maniacal attacks the patient must be fully controlled and guarded, but with as little manifestation of restraint as possible; failing other drugs, hyoscin in doses of $\frac{1}{200}$ to $\frac{1}{100}$ grain will sometimes succeed in quieting the patient, but must be used with great care, as it is a severe depressant. Nourishing food of a fluid type should be administered during the quiet intervals, and free purging is of course essential. The patient usually recovers from a first attack, but in the later ones may die of heart failure or exhaustion.

Fat embolism results from the absorption of broken-up fat globules after any injury which causes contusion or laceration of fatty tissue; when this is accompanied by tension from effusion of blood, as in fractures, this process is more likely to occur. Usually the greater part of the fat absorbed is filtered off by the lungs or eliminated by the kidneys (as can be demonstrated after death by staining with osmic acid), and no harm results. The pulmonary obstruction may, however, become so great as to lead to a fatal issue from dyspnœa; whilst if the cerebral vessels are blocked, syncope, or even coma, may be induced. The symptoms are gradual in their onset, and usually commence about the third day, but may not be evident for a week. It is a rare complication.

Union of Fractures.—The broken ends of the bone are left rough, spiculated, and more or less separated one from the other; the periosteum is torn, but the rupture is not always complete, a 'periosteal bridge' covered with osteoblasts perhaps persisting and playing an important part in the reparative process, especially if correct alinement is not obtained. The muscles and neighbouring tissues are lacerated, and a varying amount of blood is extravasated, occupying the interstices of the wound. In the course of a few hours after the parts have been immobilized, the process of repair is inaugurated by the blood-clot becoming invaded by leucocytes, and after a time it is absorbed, the hæmoglobin passing through various stages of degeneration, and thereby staining the surrounding tissues. At the same time all the injured and lacerated soft parts around become hyperæmic, and the connective tissue cells therein proliferate actively. The periosteum becomes thickened and more vascular, and its connection with the bone is loosened for a short distance on each side of the fracture. Thus the whole area of the lesion, limited more or less by the torn and loosened periosteum, is converted into a cellular mass, in which a gradually diminishing amount of blood-clot is present. This is vascularized from the tissues around, and after passing through a stage practically identical with the granulation tissue of the soft parts is converted into soft vascular bone, known as *callus*. The ossification of the vascular and cellular exudate is always determined by the activity of osteoblastic cells, derived either from the exposed

and damaged bony tissue or from those always present on the under surface of the periosteum. Wherever these travel they retain their bone-forming potentialities, and hence the ossification of the cellular exudate is rapid, as it can be carried on from many foci.

1. On the outer aspect of the fragments beneath the torn and stripped-up periosteum the amount of the cellular exudate depends on the fixation or otherwise of the fragments, and on their vascularity. The underlying bone surface becomes more vascular than usual and less dense, the entrances to the Haversian canals being enlarged. Ossification is quite early in starting, and spreads from the bone towards the periosteum. It is upon the ossification of this external or *ensheathing callus* (Fig. 268, A) that the loss of discontinuity of the two fragments depends in the early stages. When a periosteal bridge has been left between the fragments, bone formation commences on its under surface, because of the continued activity

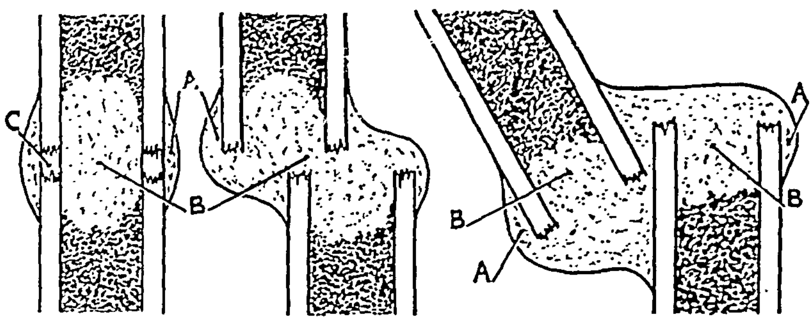


FIG. 268. FIG. 269. FIG. 270.

DIAGRAMS TO REPRESENT UNION OF FRACTURES: FIG. 268, WHEN THE ENDS ARE IN CLOSE APPOSITION; FIG. 269, WHEN THE ENDS ARE ONLY PARTIALLY APPOSED; AND FIG. 270, WHEN THE FRACTURED SURFACES ARE NOT IN CONTACT AT ALL.

A, External or ensheathing callus; B, medullary plug or internal callus; C, definite or permanent callus.

of the osteoblasts stripped off with it; in skiagrams a line of newly-formed bone can not unfrequently be seen passing from one fragment to another, especially on the concave side, if there is still some degree of angulation, and evidently due to this cause.

2. Similarly changes occur in the medullary cavity—at first, hæmorrhage; then absorption of the blood-clot, and its replacement by a cellular exudate; then a certain degree of absorption of the bony walls, which become more vascular than previously; and finally from the bone ossification starts in the cellular exudate, which becomes thus transformed into a plug of soft bone, extending up and down the medullary cavity for a varying distance on each side, and perhaps, if apposition of the fragments is not perfect, becoming continuous with the external callus. This is known as the *internal callus* or *medullary plug* (B), and assists in maintaining the continuity of the limb during the earlier stages of the process of repair.

3. Naturally the compact bony tissue is the last to engage in these

changes, and the denser the bone, the longer they are in being completed. The fractured ends become hyperæmic, the Haversian canals are dilated by absorption of their lining walls, and the bone cells proliferate, so that on section the bone assumes a more spongy texture than usual. In time it becomes converted into a tissue which is practically identical, and becomes continuous with that of the internal and external callus. Thus is developed the annular bond of union between the two layers of compact bone which used to be termed the *definitive* or *permanent callus* (C).

It will be obvious that the continuity of a bone is restored long before repair is completed, and that it mainly depends on the ossification of the ensheathing callus, the amount of which is to some extent proportional to the degree of mobility of the fragments. A certain formation of cartilage often occurs in the process of bone repair, especially in young people, and where there is much mobility; it is present chiefly in the early stages, and mainly in the ensheathing callus. The newly-formed osseous tissue is at first soft and spongy, but gradually becomes denser; at first it is easily detachable from the underlying bone, but later on is continuous with it. As the so-called definitive callus increases in strength, the ensheathing callus is absorbed, and finally, if the ends are in good position, may vanish entirely, whilst the medullary plug may also be totally removed. Thus it is possible for the bone, under these circumstances, to be restored so absolutely as to show no signs of its having been fractured.

When the ends of the bones partially overlap (Fig. 269), the amount of ensheathing callus is considerably increased, and fills up all the spaces left by the overlapping of the fragments. The projecting edges of bone become rounded off, and the medullary cavities closed by plates or plugs. The main bond of union is the ensheathing mass, a considerable portion of which persists. Some deformity is certain to remain, and it is unusual for the medullary canal to be restored.

If the fractured ends overlap completely, but remain in contact (Fig. 270), the union is secured by a large mass of ensheathing callus (A), whilst the medullary cavity of each fragment is closed by a plate of internal callus (B).

If the fractured ends overlap, and are kept from contact by the interposition of muscular tissue, union rarely takes place, and an ununited fracture results. The same occurs if the fragments are widely separated, as in the patella. In these cases but little change takes place in the bone at first beyond the closure of the medullary canal or of exposed cancellous spaces by granulation, and then by fibrous tissue; at a later date the bone ends are likely to undergo a certain degree of atrophy dependent on the amount of disability.

Where *comminution* has occurred, the splintered fragments are matted together by an abundant cellular exudate, which is subsequently transformed into callus. Each of the fragments may become a centre of ossification, and it is astonishing in some of these cases to note the rapidity with which extensive shattering is made good in the absence of infection or great displacement. Sometimes, however, fragments of *compact* tissue may remain for a long time

unchanged and with no sign of repair, and may even constitute a cause of non-union by being wedged between two fragments, thus keeping them apart.

The removal of the clot and the formation of the cellular exudate usually takes about a week or ten days, and new bone formation commences about the end of the first week. By the second or third week, according to the size and vascularity of the bone and the recuperative power of the individual, the fracture will be consolidated, but, of course, cannot bear any serious strain. In the leg it is often eight or ten weeks before the patient can bear any weight upon it, and three to six months must usually elapse before a patient should be allowed to walk on a fractured thigh.

The soft tissues around—muscles, tendons, etc.—are repaired in the usual way, but owing to their laceration and infiltration with blood the muscles may become the seat of marked fibrous changes interfering with their contractile power, or may be fixed more or less firmly to the bony surface over which they ought to play smoothly, or may be matted together and lose to some extent their power of independent movement. Tendons often become adherent to their sheaths, or may be embedded in a mass of cicatrical tissue, and hence the mobility of distal parts may be impaired in spite of the union of a fracture in good position. Neighbouring joints may become stiff as a result of periarticular infiltration, resulting in contraction of ligaments. Nerves and vessels may be torn by the displacement of the fragments, or compressed in cicatricial tissue or callus—and hence the functional result of the union of the fracture may be very disappointing.

In conclusion, one may allude to the fact that a sarcoma sometimes develops at the site of fracture within a comparatively short time of the accident. It is always, however, a question whether the sarcoma was not existent beforehand, and the determining cause of the fracture.

First Aid.—In moving the patient from the spot where the accident happened, it is necessary to secure the limb temporarily in as good a position as possible; splints have often to be improvised from sticks, umbrellas, newspapers, and so forth. In a railway accident the splintered débris of the carriages may be employed for this purpose, and the upholstery of the seats as padding. A broken leg may also be firmly tied to the other limb, which is thus converted into a temporary splint.

The **Treatment** of simple fractures resolves itself into three desiderata, *viz.*: (1) The remedying of the deformity due to the solution of continuity in the bone, and its restoration to a true alinement, *i.e.* accurate 'setting' of the fracture, as it used to be termed; (2) the fixation of the limb in such a manner as to permit the fragments to unite with a minimum of deformity; and (3) the maintenance and restoration of the function of the limb.

I. The **reduction of the deformity** and the restoration of the bone to correct alinement require a careful study of each lesion and the effect produced on the position of the fragments by the muscles of the part. The deformity, as already stated, is due to three main

factors, *viz.* the causative violence, the action of gravity, and the pull of muscles. The chief methods employed to overcome these are extension of the limb by traction, relaxation of the affected muscles by position, and careful manipulation to place the fragments in apposition; the effect of gravity is overcome by supporting the limb. Not unfrequently it is possible by flexion of a neighbouring joint to relax all muscular tension, and the fragments then fall into position almost without manipulation; in more troublesome cases longitudinal traction upon the distal end of a limb with the joint above the fracture fully flexed will permit of suitable coaptation of the fragments. One cannot insist on this too strongly in reference to fractures below the knee; flexion of the knee relaxes the gastrocnemius and therewith the tendo Achillis, and it is often easy to reduce a fracture with a bent knee when traction with the limb straight has completely failed. Care must also be taken to ensure that no abnormal rotation is present, and to this end the sound limb must be uncovered for purposes of comparison.

As the manipulation is always painful and may elicit muscular spasm, it is often necessary to administer an anæsthetic, and it may be wise to make the attempt with the assistance of the radiographic screen. No undue delay should occur in undertaking the putting-up of a fracture, as stiffness and infiltration soon follow and make the operation more difficult, but it is always desirable to delay it for a few hours, in order to treat shock, or to prepare the patient for an anæsthetic.

The recognition for the need of **Prolonged Extension** in the treatment of certain fractures of the shafts of the long bones makes it necessary to draw special attention to the principles underlying this procedure, and the means available for securing their correct application.

1. *Sufficient force must be employed to counteract muscular contraction and spasm,* which are the chief elements in maintaining the deformity. Formerly the application of a weight of 7 to 10 lbs. under unsuitable conditions was usually thought to be ample for a fractured femur; but the results obtained were certainly not satisfactory. In the thigh of a muscular adult a weight of from 10 to 20 lbs. acting freely is probably by no means too much.

2. Since the object of the extension is to stretch the muscles which control the fragments, it is most important to secure a *sufficient grasp* of these structures. The femur, for example, is surrounded by muscles, all of which, whether extensors, flexors, or adductors, are assisting in pulling up the lower fragment. The whole muscular envelope needs to be stretched, and if this is effectively performed, the bone ends are much more likely to become satisfactorily approximated. It is insufficient, therefore, to apply the adhesive plaster merely up to the line of fracture; the whole muscular envelope up to the next joint should be included.

3. At the same time *joints must be left free* to allow of mobilization at an early date. For the femur, the adhesive plaster may be prevented from touching the skin over the projecting femoral condyles by

bandaging over them a piece of gauze or lint; for fractures of the leg bones, the projecting malleoli must be protected.

4. It is essential that *the limb should be slung clear* of the bed, so that the *traction* may exercise its full power without frictional resistance. Long rigid splints must also be excluded from the dressing if the extension is to be effective. Short splints guarding the fragments of the bone and helping to keep them in position may be of use, but must not extend beyond the neighbouring joints. Skeleton splints of the Thomas or Hodgen type avoid these difficulties.

5. Effective *counter-extension* must always be provided, and in the lower extremity the weight of the body is effective in this direction if the lower end of the bed is sufficiently raised; with the heavier weights now employed, the bed-end must be raised more than was formerly the custom.

6. It is essential to *control treatment* of certain fractures, *e.g.* oblique ones of the femur or humerus, *by radiography* of the limb at intervals during the treatment to make certain that no slipping of the fragments has occurred, and this is most important during the early stages, as it is easy to correct mistakes whilst the union is still plastic.*

In cases where, in spite of suitable extension combined with relaxation of muscles and manipulation, it has been impossible to secure or maintain coaptation of the fragments, operative measures will have to be considered (p. 548).

7. The importance of securing union with correct alinement of the fragments cannot be exaggerated, for although one cannot promise without doubt that perfect function will be recovered, and although all surgeons can produce cases where good function is associated with defective alinement, yet statistics prove incontestably that good functional results are much more likely to occur if the restoration of the bone is as nearly perfect as possible.

II. The **fixation** of a fractured limb, so as to permit of suitable repair of the bone, involves (A) the application of splints and similar contrivances in order to keep the approximated fragments in correct position and alinement, or (B) the adoption of operative treatment.

A. **Splints** may be made of wood, leather, poroplastic, etc., according to the requisites of the case. If of wood or metal, they are usually made according to some general pattern, and fitted to the patient by means of pads. If formed of leather, papier-mâché, or poroplastic, they can be shaped so as to meet any peculiarities of the part, softened by immersion in hot or cold water, moulded to the limb, and allowed to dry. Where leather is employed, the addition of a little vinegar to the water assists in rendering it soft and supple. The edges and corners are finally rounded, and the interior padded with wool or lint. Splints must be sufficiently large to encase the part firmly, or, if flat, to project a little beyond it, so that the limb may be fixed by the splint, and not the splint by the limb. In all cases careful attention must be given to the padding, so as to prevent irritation

* Where many fractures are likely to be treated a portable X-ray machine is essential, and hospital authorities must be urged to provide this in spite of its cost; in the long run it will prove to be an economy.

of or undue pressure on the skin, which may result in splint sores (p. 100). In out-patient practice, where patients are not too careful as to personal cleanliness, it is advisable to pad the splint with some antiseptic material, such as boracic lint, in order to prevent the development of vermin, but in all cases it is wise to shave and purify the limb, and to dust it over with boric acid and starch. When blebs or blisters have developed, a dry aseptic dressing should first be applied. The splints may often with advantage be fixed to the limb by one or two strips of adhesive plaster, and then secured by ordinary calico bandages; these must not be applied too tightly, since the limb not unfrequently swells after the accident, and undue constriction resulting in gangrene might ensue. Moreover, a limb ensheathed in bandage must never be flexed, but the flexion should always be made beforehand; otherwise the bandage may cut into the soft tissues, and by compression of the vessels cause gangrene. The condition of the fingers or toes is a sufficient test as to the activity or not of the circulation.

In all cases where prolonged extension of the limb has to be maintained, the employment of the form of splint described above is not satisfactory, and *skeleton splints* of the type devised by Hodgen or Thomas are now generally used, suitably modified for arm and leg.

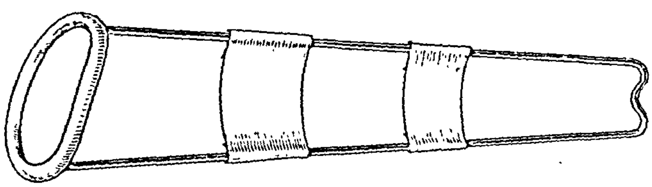


FIG. 271.—THOMAS'S SPLINT AS EMPLOYED FOR FRACTURE OF THE LEG.

The essential element of Thomas's splint (Fig. 271) is a well-padded ring above, through which the limb is passed; it is pressed home either against the chest wall and axilla, or against the tuber ischii. The skin against which it rests must be shifted from time to time and well protected, so as to prevent the development of splint sores. On either side a straight or bent iron bar passes down, attached above to the ring, and terminating below in a cross-piece, the level of which is well below the sole of the foot or tips of the fingers. Extension arrangements are fixed to the limb by glue or adhesive plaster, or by some form of skeletal traction apparatus (see p. 614), and attached to the cross-bar of the splint or connected with a weight hanging over a pulley; this will drive the upper end firmly against the point of support. Counter-extension for the leg is obtained by tilting up the lower end of the bed, so as to utilize the patient's weight for this purpose. The limb itself is supported between the longitudinal bars as in a trough by securing to them bands of flannel, rubber, or metal by means of safety-pins or spring paper clips. Deflection of one or both fragments to either side can be corrected by passing a broad flannel band round the limb and drawing it to the opposite bar to which it is secured, or more certainly by the application of carefully padded hollow metal

plates fixed to the sidebars and with screw adjustments; sagging downwards of the fragments is corrected by tightening the bands forming the trough; displacement forwards, by passing a band above the limb and attaching it to either bar. In this way slight modifications are easily made. Sometimes the additional incorporation of short splints in front or behind is of considerable importance in steadying the parts.

Of great value in treating fractures of the lower end of the femur by skeletal traction is Braun's splint, because it enables movements of the knee-joint to be readily carried out. It is also of great value in treating fractures of the leg.

In the treatment of fractures where the tendency to displacement is slight, *e.g.* transverse fractures, and where in children difficulties of fixation by splints occur, various forms of **Fixed Apparatus** are used; they are also of value in the later stages when other splints are not required. The materials most commonly employed are starch and plaster of Paris.

The *starch* bandage is utilized only in cases where great strength and rigidity are not required. After placing the fracture in good position the limb is covered with boracic lint, and over this, if necessary, are applied thin strips of cardboard soaked in starch. These are firmly secured by bandages, into the meshes of which is rubbed a suitable solution of starch. When this dries it produces a firm mass, sufficient to immobilize the limb. Should it become loose, it can easily be readjusted by slitting up and paring away a portion of one or both sides.

Plaster of Paris, though rather messy and increasing considerably the weight of the limb, is one of the best means of securing prolonged immobilization. The dried plaster may be rubbed into a coarse crinoline or gauze bandage, which prior to use is soaked for a few minutes in cold water, to which a little salt or alum may be added in order to hasten its setting; it is then wound round the limb, which has been previously enswathed in boric lint or wool, and on the exterior of this fresh plaster of the consistency of cream is applied. To make this cream of the right strength the dried powder is cast in spoonfuls into a bowl of cold water until it no longer sinks immediately, but remains floating on the surface. The mixture is then stirred with an iron spoon, and is ready for use. When the casing is sufficiently thick, the outer surface is smoothed down with wet hands, or a strip of wet bandage; the date may be advisably marked on it, and the part is slung up to dry. The plaster case may, later, be cut into two halves, or 'bivalved,' by means of suitable shears, in order to facilitate massage.

B. The increasing success of modern aseptic surgery has given considerable impetus to the **Early Operative Treatment** of fractures in order to secure perfect alinement, complete fixation, and the early restoration of function. This plan was first advocated and utilized by Lord Lister for such bones as the patella or olecranon, but its adoption for the long bones was largely due to the teaching and example of Sir W. Arbuthnot Lane.

The turning of a closed fracture into an open one is not to be looked on as a serious hindrance, granting that aseptic precautions are carefully observed; at the same time one cannot but recognize that an added element of risk is thereby introduced into the case. Possibly, in the more recent past, surgeons were more keen on developing their operative skill than on perfecting mechanical devices which shall avoid operation. One of the greatest lessons of the late war has been to emphasize once again the teachings of Hugh Thomas as to the value of the skeleton splint, and the adoption of this method of treating fractures in civilian life will limit considerably the operative activity of surgeons in this direction. Of course, the great advantage of operation is that it fixes the fracture so securely as to permit of early massage and movement of neighbouring joints; atrophy of muscles and stiffness are thereby avoided, and the economical depreciation in value of a working man after, say, a fractured tibia may be to a large extent prevented. One cannot but believe, however, that if similar care is given to such cases treated on appropriate lines without operation, similar good results will be obtained. So long as the old-fashioned plan persists of fixing the joints above and below a fracture in apparatus troublesome to put on and take down, or in a rigid plaster of Paris case, until complete consolidation has occurred, and massage and movements are only employed to remedy stiffness already acquired, so long will bad results be turned out, and operative activity be justified.

The actual *selection of cases for operation* must necessarily vary with the views of the particular surgeon, but the following may be looked on as a fair statement of the case:

1. Fractures of small bones or of processes which are not easily retained in position by external appliances, and where healing apart from operation is slow and often defective, *e.g.* in the patella, olecranon, etc., require operation.

2. Fractures involving joints, where fragments are displaced, as when the condyles of the femur or humerus are detached, may sometimes be operated on with advantage.

3. Fractures of the shafts of long bones which are oblique or spiral, with much longitudinal displacement and perhaps overlapping, and with the sharp ends of the fragments impacted in muscular or other tissues, can often be placed in good position only by open operation, and even then perhaps with some difficulty. In situations where extension cannot be easily applied, and reduction by manipulation fails, *e.g.* in some fractures of the forearm, operation is justifiable.

4. Fractures of the shafts of long bones which can be brought into good position by suitable extension should, as a rule, be treated by means of Thomas's splint or of some modification thereof, rather than by operation. Where effective extension can be made and maintained, an open operation may almost be looked on as a confession on the part of the surgeon of insufficient knowledge or inefficient apparatus.

The *time for operation* must be carefully considered; it is usually wise to delay it for a few days, partly to allow the patient to recover

from the shock of the accident, partly to permit of effective purification of the limb and its radiographic examination, and partly to allow those early reparative changes to occur in the tissues of the part, which also assist in protecting them from infective troubles. Any time between the fourth and tenth days will be satisfactory. During the interval of waiting it is wise to apply effective weight extension so as to prevent any increase in the deformity and to reduce the amount of manipulation required at the operation.

The **operation** itself must be conducted with the most minute care as to aseptic precautions. The skin must be previously shaved and purified, but all direct handling of the wound is to be avoided, manipulations being carried out by means of instruments which have been sterilized by prolonged boiling. The long-handled instruments devised by Lane are particularly suitable for this work. Gloved hands are employed. Spinal analgesia is often useful for the lower limb so as to secure complete muscular relaxation. The incision should be planned so as to give effective exposure to the site of fracture, and allow exit to as much of the extravasated blood as possible. The surrounding skin should be protected by towels clipped on the wound margins. The ends of the fragments are exposed, cleared, brought into correct position with as little manipulation as possible, and held by suitable forceps, whilst their fixation is being accomplished. After this has been effected, the displaced periosteum is, if possible, drawn together so as to limit the field of activity of the osteoblasts and to prevent adhesions of the muscles to the bone; divided muscles are sutured together with deep sterilized catgut stitches; provision is made for temporary drainage if thought necessary; the deep fascia of the limb is carefully sutured, as also the skin. A suitable splint is then applied, and the patient returned to bed.

Various *methods of bone fixation* are available, and it is not always easy to determine which to employ. Much ingenuity has been exercised in the production of some of these, but most of them will be found in the near future rather in the museum than in the operating room.

1. Sometimes it is sufficient to hold the fragments together by *silver wire* of appropriate thickness, *e.g.* for the patella or olecranon, or for some oblique fractures of long bones. For the latter it is desirable to transfix the bone in two positions and introduce the wire as a mattress suture, and in a very oblique fracture two such sutures are desirable instead of one. Care must always be taken to tighten the wires securely by twisting, but not to twist off the ends; the knots must be bent over and beaten down, so as not to cause irritating projections.

2. When the fracture extends through masses of cancellous tissue, *e.g.* the condyles of the femur, or has involved fragments covered with muscular origins, the complete displacement of which would be undesirable, *e.g.* the condyles of the humerus, it is often possible to fix the fragment in position by *screws, nails, or pegs* of bone or ivory. It is usually desirable to introduce two of these, so as to protect the fragment from displacement during the interval between withdraw-

ing the drill and introducing the peg, as also to secure the fragment, when fixed, from rotation. Autogenous bone pegs, cut from the tibia by a double circular saw, *e.g.* Albee's, and rounded by an electrically driven dowel-shaper, are more satisfactory than metal screws or nails; they are introduced into a suitable-sized hole and driven home by a hammer, any excess being cut off, so that there is no projection.

3. *Intramedullary pegs* of metal or bone have also been employed, but are not so generally applicable, in that their introduction involves a good deal of displacement of the fragments; they do not secure so

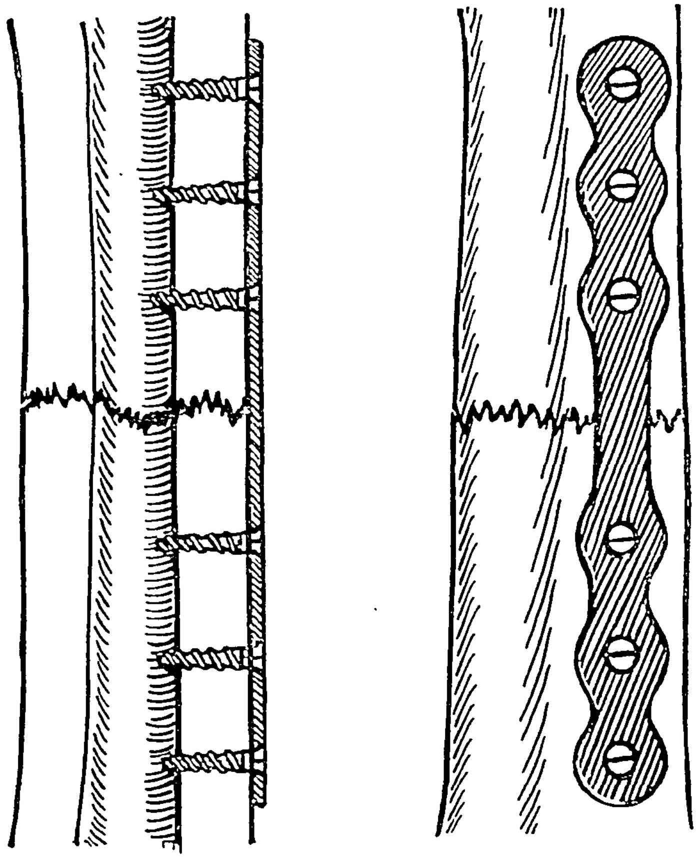


FIG. 272.—LANE'S PLATE APPLIED FOR TRANSVERSE FRACTURE WITH DIAGRAMMATIC LONGITUDINAL SECTION.

perfect an immobilization, and should the operation by mishap be followed by sepsis their removal is most difficult.

4. For fractures through the shafts of long bones, **Lane's plates** (Fig. 272) have been largely employed. They consist of flat metal plates which can be bent by suitable wrenches to fit accurately to the contour of the bone. They are supplied with a varying number of holes for screws, according to the type of fracture; holes are drilled through these into the bone, so as to reach the medullary cavity. For a fractured tibial shaft at least four screws are required, and for a femur six or eight.

Experience has, however, shown that there are many objections to their employment as a routine method of treatment, and they are now but little used. (*a*) It is essential to secure a firm hold of each fragment by the use of a *long* plate; this involves considerable interference with the soft tissues, thereby interfering with the nutrition of the bone. (*b*) Absolute fixity of the fragments without the possibility of the slightest movement does not conduce to rapid or effective union; the best results are secured when it is possible for the ends to rub one against the other without displacement. Non-union in the ribs is unknown; delayed or non-union after 'plating' is not uncommon. (*c*) The local effects of the screws on the bony tissue is to cause rarefaction, so that the firm hold is lost in a short time. If splints or other retentive apparatus are removed too soon, so that powerful muscles can come into action, displacement and deformity may readily appear, especially in the shaft of the femur. (*d*) Infection of the wound is almost always associated with death of the portion of bone lying under the plate, and may reach the medullary cavity through the screw holes. Delayed auto-infection may also occur, arising in the small hæmatoma or from the damaged tissues around the plate. (*e*) It is hardly needful to say that metallic plates or wires should never be used for an open fracture owing to the presence of sepsis, which must be assumed in every case.

5. **External clamps** connected with long removable screws have been advocated by some authors, *e.g.* Hey Groves, but their employment is not generally recommended or feasible.

6. In conclusion, one would note that all metal appliances are undesirable in the fractures of children; silver wire is the least objectionable; nails and screws, especially near joints, may light up inflammatory mischief; the screws of bone plates are early loosened by rarefying inflammation, so that this proceeding is not very reliable; catgut or silk sutures passed through the periosteum so as to hold the fragments temporarily in position or autogenous bone pegs should be chiefly relied on. Every effort must be made, however, to avoid operation for fractures in children.

III. **Massage and Mobilization** nowadays play an important part in the treatment of fractures. The days of prolonged splinting and immobilization are over (or should be), and splints are looked upon as undesirable necessities to be discarded as soon as possible and replaced if need be by light removable plaster of Paris supports, which protect from injury and displacement a weakly united fracture between the intervals of exercise and massage. Under the old régime the functional results of treatment were extremely bad in the aggregate; the limb remained for a considerable period weak and stiff, owing partly to atrophy of muscles, partly to cicatricial adhesions, and in part to contraction of ligaments in neighbouring joints, and these disabilities increased in direct ratio to the length of time that the limb had been kept at rest. The modern surgeon endeavours to prevent these disabilities, but this can only be effected by persistent attention and methodical after-treatment.

In the earliest stages massage may be employed in the shape of

gentle stroking movements to relieve pain and diminish muscular spasm. Thus diagnosis is facilitated, since the patient permits the limb to be handled and gentle movements to be undertaken, and reposition of the fragments may become practicable.

In fractures through the shafts of long bones with displacement, which, apart from operation, may possibly recur, the part is necessarily immobilized by a suitable appliance; but although the joints above and below the lesion are included in the apparatus, there is no need to keep them immobile throughout the course of treatment. Indeed, it is most desirable that from a very early date they should be moved regularly, and thereby stiffness prevented, and with modern appliances of the Thomas type this is perfectly feasible. Massage is employed in these cases to tone up muscles, as well as to assist in the absorption of blood, etc. Possibly some pain is noticed at first, but it soon disappears if the massage is gentle and not too forcible. Of course, the patient is not allowed to put any strain on the part by active movements until the consolidation of the fracture is assured. Where the tendency to displacement has been remedied by operation, the whole proceeding is necessarily easier.

In fractures near joints or through the articular ends of bones it is often possible, and indeed wise, to discard splints entirely, or at any rate only to use them for a short time, steadying the part by some simple contrivance, such as a sling or strapping; massage is commenced after the first few days, and if of the gentle and soothing type is most comforting, and will enable the neighbouring joint to be moved passively. This method of treatment is specially applicable to such injuries as fractures of the anatomical neck of the humerus, the simpler varieties of Colles's and Pott's fractures, and for many fracture dislocations in the neighbourhood of the elbow. In such cases active movements may often be permitted at quite an early date; but if these are produced by powerful muscles, which by their attachment to one of the fragments are liable to reproduce the deformity, then passive movements and massage must be relied on until the fracture is consolidated, and there are conditions about the elbow where even passive movements must be refrained from for a time. In spite of all precautions, however, a certain percentage of cases under this heading are certain to develop permanent stiffness to a varying degree.

Ambulatory Treatment.—Certain fractures in the lower limb, *e.g.* tibia and Pott's fracture, may be treated by fixation in a plaster of Paris splint, in which the patient is allowed to walk, after allowing a few days for the preliminary swelling to subside. The active muscular contractions thus obtained, together with the slight movement of the fractured surfaces, are conducive to rapid consolidation, and minimize the need for subsequent massage.

It is advisable to protect the plaster from direct contact with the ground, either by a metal stirrup of the Böhler pattern (Fig. 346, p. 630) or by a wooden sole-plate.

Finally, a word of caution must be given against too forcible and vigorous massage and movement, which can readily induce pain,

muscular spasm, and increasing stiffness. This is particularly the case when the line of fracture involves a joint, and then natural movements carefully graded are often more valuable than forcible passive exercises. The onset of pain as the result of massage or movement is always an indication to keep the parts at rest for a few days longer.

Complications of Fractures—1. **Implication of a Joint.**—When the fracture extends through the articular cartilage, the joint becomes distended with blood and synovial fluid, but this is subsequently absorbed, and the fissure in the cartilage closed by plastic lymph, which develops into scar tissue. If the fragments are in perfect apposition, no permanent harm need result if treatment such as that recommended above is undertaken. If, however, the apposition is imperfect, adhesions of a more serious type develop, and considerable limitation of movement may follow. It is thus comprehensible that one of the chief indications for the operative treatment of fractures is when they involve joints. In elderly people injuries of this type may result in a chronic traumatic arthritis, particularly in the shoulder or hip, causing pain and limitation of movement by the development of osteophytes. In some of these cases massage seems to do harm rather than good.

2. The same violence that causes the fracture may at the same time produce a **Dislocation** in a neighbouring joint, and particularly in connection with the elbow and shoulder. Treatment should always be undertaken as soon as possible. Should the fracture involve or be close to the articular end of the bone, an attempt should be made to reduce the deformity by manipulation under an anæsthetic; failing this, or if the deformity recurs, open operation should be undertaken if the conditions as to surgical cleanliness permit. In most cases the dislocation can be reduced after removing the extravasated blood, and the fracture fixed; but sometimes, when the displaced articular fragment is small, it is wiser to excise it.

When the fracture is further away from the joint, it is sometimes possible to command the fragments by splints, and then reduce the dislocation under an anæsthetic. Should this fail, the surgeon may either fix the fracture by operation and repeat the attempt to reduce the dislocation, or he may open the joint and perform an open reduction. Should immediate treatment be impracticable, the limb should be fixed in splints so as to allow union of the fracture, and at a later date the unreduced dislocation should be treated.

3. The **Main Artery** may be compressed, contused, punctured, or ruptured, giving rise to thrombosis, aneurism, or hæmorrhage. In the former case, dry gangrene may result if the terminal vessels are unhealthy; in the latter, moist gangrene may be produced by the pressure of the extravasated blood on the veins. This is most frequently observed in fractures of the lower end of the femur, where the femoral or popliteal artery may be involved. **Treatment** has been discussed elsewhere (p. 102). Here it may only be mentioned that in the case of a ruptured artery operation should, if possible, involve not only the removal of the blood-clot and the securing of the artery, but also the fixation of the fracture.

4. Laceration of **Veins** results in extravasation of blood, which is not so extensive as when an artery is wounded, since thrombosis occurs more easily; the distal part of the limb may become congested and œdematous, and this may require for its removal firm bandaging and massage. Pulmonary embolus is an occasional sequence of venous thrombosis.

5. The **Nerves** of a limb may be injured at two different periods. (*a*) Immediate injury is due to laceration or rupture, either of the whole trunk, or, as is more common, of the nerve fibrillæ, without loss of continuity of the sheath. (*b*) Secondary symptoms result from inclusion and compression of the nerve in the callus, or from injudicious splint pressure. Irritative symptoms in the shape of neuralgia are first manifested, followed by paralysis and anæsthesia. This usually occurs three or four weeks after the accident, and may disappear in a month or two, or persist. **Treatment** is always for a time of the expectant type, even when the paralysis is immediate, since total rupture of a nerve is rare, and restoration of function the rule rather than the exception. When, however, the symptoms persist, the parts must be laid open, the nerve freed from adhesions, or exuberant callus removed, and such measures taken as will best secure the nerve from further compression (Chapter XV., p. 383).

Complications arising during Treatment.—(1) If an elderly patient is kept in bed for any length of time in the recumbent posture, *hypostatic pneumonia* is likely to ensue. It occurs most commonly after intracapsular fractures of the cervix femoris, and non-union often results, since the patients must be allowed to get about on crutches at an early date with the limb fixed by a suitable splint. (2) *Bedsores* (p. 100) are liable to supervene in old people with fractures which need treatment in the recumbent posture. (3) *Crutch palsy* is the result of compression of the brachial nerves between the head of the humerus and the pad of a crutch. It may affect all the nerves of the upper extremity, or may pick out any one of them, and then most commonly the musculo-spiral. It can usually be prevented by the use of spring-padded crutches with cross-pieces for the hands, so as to allow the patient partially to relieve the axillary pressure by supporting the weight of the body by means of the arms, or by the employment of the modern stick-crutch. When it has occurred, the use of crutches must be discontinued, and faradism and massage employed to the affected muscles. (4) *Volkmann's contracture* (p. 464) sometimes develops in cases of fracture of the forearm or elbow in children. (5) Another muscular complication consists in a deposit of bony tissue therein, a result of a *myositis ossificans* (p. 466). (6) *Gangrene* may arise from fractures in a variety of ways: (i.) From the immediate effects of the injury, either by its direct action on the tissues, or by causing arterial thrombosis in a limb with atheromatous vessels, or from rupture of the artery with consequent venous thrombosis, owing to the pressure of the extravasation; (ii.) by the supervention of spreading gangrene in a compound fracture; (iii.) from errors in the course of treatment, as by bandaging the limb too tightly, so as to constrict the vessels; or by the bandage becoming unduly

tight, owing to the subsequent swelling of the limb; or by flexing a joint after bandaging it, the bandage cutting into the soft tissues; or by the localized pressure of a splint which has been insufficiently padded. Moist gangrene is the type met with in all cases, except when the limb has been previously drained of its fluid by an atheromatous condition of its vessels.

(7) *Splint sores* constitute a form of localized gangrene due to the pressure of a badly fitting or imperfectly padded splint, or possibly to bandaging on too tightly a splint which otherwise would be satisfactory. The commonest situation is over the heel when the limb has been kept for a time on a back splint with a foot-piece; it is also sometimes seen on the outer or inner side of the leg when side splints have been too firmly applied. When of considerable size, the parts must be purified carefully, all pressure removed, and antiseptic fomentations applied to assist in the removal of the dead tissue; the sore resulting therefrom will require stimulating applications to encourage healing. When the slough is of small dimensions, it is kept aseptic and allowed to be absorbed by natural processes.

Open (or Compound) Fractures.

An open fracture is one in which there is a communication between the external air and the site of injury. It is caused by direct or indirect violence, the solution of continuity of the skin being produced in the former from without, and in the latter by the penetration of a bony fragment from within. It is also sometimes secondary to treatment, the skin over the fracture sloughing as a result of pressure or irritation. The bone may be but little displaced, or may protrude through a small opening in the skin; or the bone may be crushed and comminuted, and a large fleshy wound may be associated with it. In some of the injuries produced by railway or machine accidents, gunshot wounds, or motor-cars, the skin and muscles are violently torn across, and the underlying bone may be pulped, whilst road dust, grease, and dirt of many types are ground into the tissues.

The chief peculiarities of open fractures are due to the existence of the external wound, which permits of the entrance of bacteria into the depths of the limb, and perhaps interferes seriously with the application of splints and other appliances.

Hæmorrhage occurs to a variable degree according to the size of the vessels involved; but inasmuch as the lesion is not usually produced by cutting, the vessels may become sealed by natural processes. Secondary hæmorrhage is not uncommon in septic cases, as the result of a periarteritis, particularly if a sharp fragment lies in close contiguity to a large vessel.

Infection is caused by any of the multifarious types of germs found in the skin, dirty clothes, road dirt or soil. The ordinary pyococci are almost always present, together with anaërobes, coliform bacilli, and organisms of the proteus type. Any or all of the parts involved may become the seat of suppurative lesions which have a considerable tendency to spread. Thus cellulitis may develop in the subcutaneous

tissues, and erysipelas sometimes occurs. The deeper planes of cellular tissue are also involved, and this may be followed by wide burrowing of pus. The possibility of the development of tetanus must also be remembered.

Muscle bellies often protrude through the opening in the deep fascia by which they suffer constriction, and present as an œdematous mass which may even become gangrenous; drainage of the deeper parts of the wound is thereby hindered. Anaërobic invasion may lead to localized gas gangrene.

Tendon sheaths, if opened, provide a favourable nidus for the development of pus organisms, and the suppuration may track up or down for a considerable distance; the tendons themselves slough or contract dense adhesions to the sheath.

The effect on the *bone* varies. If the shaft is broken cleanly, an acute osteomyelitis may follow if drainage is defective; but if there is a free exit to discharges, all that may result is a limited necrosis of the compact tissue of the end of one or both fragments. If the fracture involves cancellous tissue, an acute infective osteitis follows, leading to cario-necrosis, and possibly by direct extension involving neighbouring joints and bones. The existence of *fissures* extending from the main focus of the lesion does not necessarily involve a spread of the suppuration along them, unless rough handling, or injudicious movement, or tension from want of drainage, is present. When *comminution* is present, infection almost invariably leads to death of all totally detached fragments, but those which retain their periosteal connection will probably live and be useful in the reparative process if satisfactory drainage is established.

Neighbouring joints may become infected at the time of the original injury, or subsequently by secondary extension through living bone or along fissures. In old-standing cases with necrosis and chronic sepsis, joints may become stiff by prolonged immobilization, and then forcible attempts to break down adhesions and free the joint may result in lighting up an acute suppurative arthritis.

Nerves may be injured at the time of the accident, or damaged at a later date by inclusion in the callus or in cicatricial tissue. The phenomena are identical with those following a simple fracture, but unfortunately nothing can be done in the operative line to repair them until the sepsis has been overcome.

It will be manifest from the above brief generalization that whilst compound fractures may be followed by good results if treated early and effectively, delay or defective treatment may involve the patient in the gravest dangers of an infective nature (pyæmia, septicæmia, etc.), or may lead to a most wearisome and prolonged convalescence. Life and limb are alike threatened, and even if both are saved great and crippling disability may follow.

The **Method of Repair** of a compound fracture is much the same in principle as that of the simple variety, but necessarily is largely influenced by the *course of the case*.

If complete and immediate sterilization of the wound can be effected, it may be closed at once or by delayed primary suture, and

the fracture treated in the same way as one with no skin involvement. The repair is then identical in the two types. The same occurs if infection merely involves the soft tissues.

If, however, bacteria invade the bony fragments, a certain amount of necrosis is almost sure to occur, and delay in healing of the wound must ensue whilst the necrosed fragments are separating.

(i.) If the fracture is *a clean break through the shaft*, and the necrosis limited to a small section of the compact tissue on one or both fragments, the dead bone is separated by a process of rarefying osteitis in the neighbouring compact tissue; the marrow cavity is shut off by a medullary plug of soft bone, the superficial layer of which is converted into granulation tissue. Whilst this is occurring, new bone is being formed from the osteoblasts adherent to the neighbouring periosteum, and this may suffice to bridge the gap between the fragments and determine their union. The bond of union thus formed constitutes an involucrum (p. 638) to the dead bone, which lies within and is gradually separated. If the sequestrum is small, it may find its own way to the surface, but usually the external wound has narrowed to such an extent during the interval as to prevent its escape, and sequestrotomy must be undertaken. When once the sequestrum is removed, a clean granulating cavity persists, and this should heal more or less quickly according to its shape and blood-supply; the deeper part of the granulations being derived from bone is likely to develop into bone; the more superficial part into cicatrical tissue.

Sometimes, however, the presence of the sequestrum maintains so much irritation that reparative changes cannot occur so long as suppuration persists, and the fracture remains ununited; removal of the sequestrum may bring about such a degree of healthy action as to determine union.

(ii.) *In cancellous bone* a septic fracture will be followed by a spreading osteitis until efficient drainage is provided, and then the destructive process comes to an end and repair follows.

(iii.) *Comminution* of compact tissue is a serious complication in an infected open fracture. Fragments totally detached die, and, unless they are removed, cause persistent suppuration. Fragments retaining their periosteal connections live, and undergo active changes, either destructive or reparative, according to the degree of infection present. Where drainage is free, the fragments are welded together by granulations around the central cavity of the fracture, and these granulations are converted into new bone.

In cancellous tissue a similar process occurs when the parts are freely opened up and drained, and all loose fragments removed. Too conservative a policy results in the retention of both dead and living fragments, between which pus burrows, coming to the surface in various directions, so that the whole area of the injury may be riddled with sinuses. Some degree of reparative activity occurs, and in time the site of the injury may be occupied by a swelling, which consists of a curious mixture of dead and living bone, more or less carious, between the constituent elements of which lies a mass of œdematous tissue, partly granulation, partly cicatricial; sinuses

track through this mass, and the patient may become gravely ill and anæmic from toxic absorption. No repair can be expected so long as this mass persists, and cure can only be established by clearing out the whole infected area.

The **Treatment** of compound fractures has two main points in view, *viz.*: (1) To prevent the development of infection or to limit its ravages, and (2) to fix the limb in apparatus, so that repair of the bone may occur with as little deformity as possible.

The prevention of infection is really a question of time; if the case is seen early, much can be done; if there is much delay, sterilization of the wound is almost impossible. The rules already given (p. 66) must be followed out with the greatest care. The skin of the limb is shaved and purified; the margins of the wound are excised; the cavity of the wound is laid open by suitable incisions, so that the interior may be thoroughly explored. Damaged and hopelessly torn tissues are cut away so as to leave a free approach to the site of the fracture, which is appropriately dealt with. If the surgeon is satisfied, he may close the wound entirely, or may wash it with alcohol and 'Bipp' it before closure. If he is doubtful as to the result of his efforts, the Carrel-Dakin treatment may be instituted, or a flavine pack inserted—but in the latter case the gauze must not be entangled in the spicules of the bone. A counter-opening may be necessary, but *under no circumstances must a drainage-tube be carried across the site of the fracture so as to lie between the fragments*; necrosis is certain to follow such a procedure.

Winnett Orr of America has produced some astonishingly good results by thoroughly cleaning up the wound and packing it with gauze soaked in sterile vaseline, after the bone or bones have been brought into alinement by manual or skeletal traction. No attempt is made to close the wound, nor is any drainage employed. The limb is encased in plaster of Paris. The plaster is not removed for six weeks or more, when it is found the wound will probably have healed.

The treatment of the bone itself varies with circumstances. When merely a sharp end of one of the fragments protrudes through a small opening in the skin, the latter is first purified thoroughly, and then after the margins have been excised and the wound, if need be, enlarged, reduction is effected, and the wound, if thought desirable, closed. In clean breaks without protrusion, the fractured ends are apposed in the usual way and the limb placed on a suitable splint. Skeleton splints of the Thomas type are of the greatest value in compound fractures, in that the limb need not be disturbed when the wound is dressed; the flannel bands which constitute the trough in which the limb lies must be so arranged that by the removal of one or more easy access to the wound is secured.

When comminution is present, the site of the fracture should be carefully explored. All totally detached fragments are removed, but the majority of fragments which retain their periosteal attachments, especially if of large size, are saved. If the surgeon is fairly confident as to sterilization, no removal of bone other than of completely detached fragments is justifiable; if, however, he anticipates infection,

or if it is already present, he should remove by careful subperiosteal resection such loose fragments as are likely to hinder effective drainage, always leaving a sufficiency of bone to maintain the continuity of the limb.

When suppuration persists, necrosis has probably occurred, and radiography is useful in determining when the sequestrum is free. It must be remembered, however, that sequestra seldom take more than two or three months to separate, and often less. As soon as separation is effected, operation to remove the sequestrum must be undertaken; delay involves thickening and condensation of the involucrum, with subsequent trouble in determining closure of the sequestral cavity (p. 649).

All secondary operations required for non-union, vicious union, or nerve lesions must be postponed till the wound has been satisfactorily healed for some time.

The question of *amputation* has, of course, to be considered in many cases, both immediately or as a secondary procedure, and has been discussed elsewhere. It is only necessary here to remind practitioners that so much can be done nowadays by conservative means that amputation must not be decided on without the most careful consideration; at the same time it is useless to retain that which may become a source of serious danger, or even if saved remain a useless encumbrance.

As a secondary operation, amputation is needed mainly for severe recurrent secondary hæmorrhage, grave infection of the soft parts extending up the limb with marked toxæmia, a heavy infection of a neighbouring joint or of surrounding bones (as in the tarsus), or chronic anæmia and toxæmia due to persisting and long-continued suppuration. Gangrene from whatever cause also requires amputation, but not necessarily up to the site of fracture.

Chronic necrosis has been unfortunately a sequela seen only too commonly after compound fractures due to gunshot wounds, and there can be no question that for some years these cases will require treatment. The unfortunate patient retains one or more suppurating sinuses, from which perhaps small spicules of bone are discharged; this may be followed by healing which persists for a time, and then possibly, as the result of some slight injury, the wound flares up, the limb swells, and the cicatrix gives way, permitting exit to a quantity of pus. A probe is passed, and finds its way into a bony cavity along a passage which may be straight or tortuous; bare bone is touched; and the doctor not unfrequently decides to 'scrape it out.' This is done more or less thoroughly, probably through a small incision; fresh bony tissue is laid bare and infected; fresh necrosis follows; and the whole gamut of trouble is repeated. This goes on time after time, and operation follows operation for years perchance, and at the end of fifteen to twenty operations the patient is in a rather worse condition than previously, and frequently requests the removal of his limb.

The local conditions present in these cases vary considerably, but as a rule there is a sequestrum of greater or less size lying in a cavity

which is almost surrounded by bone, which becomes increasingly dense and non-vascular as the months pass, until sometimes it is as hard as ivory. It is obvious that reparative changes can only occur very slowly in such tissue, and that scraping cannot be expected to bring about healthy activity. The sinuses which reach this cavity are often narrow, and may be badly placed for drainage or dressing; the constant passage of discharges and the daily introduction of gauze packing (often too tightly) suffice to determine a spreading sclerosis in the surrounding soft tissues which will impair subsequent usefulness. Even if the sequestrum is taken away successfully without waking up fresh trouble, healing does not always occur, since the bone may be tunnelled, and the sides of a bony tunnel necessarily cannot fall together.

The treatment of these cases is often very difficult, and usually irksome both to doctor and patient, and yet they can be cured even after many futile operations.

The actual operative procedure must be governed by the following considerations: (1) A careful stereoscopic skiagram of the limb must be secured, which shall enable the surgeon to visualize clearly the conditions he is called on to treat. (2) The trouble in the bone must be approached by a route which shall enable him effectively to deal with it; if the existent sinuses happen to fall into the line of his incision, well and good; if not, the sinuses will probably close quickly after the essential cause of the trouble has been dealt with. (3) The incisions must be sufficiently long to enable *all* the trouble in the bone to be reached and dealt with openly without recourse to a curved spoon, which can scrape round a corner and only just get into a narrow passage. The ideal condition to be left after operation is a wide shallow gutter or crater with no overhanging bony lips. This necessarily involves the cutting away of a good deal of bone in many cases, for which suitable chisels and gouges are required; but the dense bone often found is very unfavourable for reparative purposes. Tunnels in the bone are treated, if practicable, by removing entirely one side of the tunnel so as to convert it into a trench into which the surrounding soft tissues may find an entrance.

The cavity thus formed is carefully dried, hot saline solution being employed as a hæmostatic; it may be then wiped over with absolute alcohol, and packed with gauze soaked in 'Bipp,' which is retained for ten days or more unless there has previously been very free discharge. If there is little discharge, frequent dressings are quite unnecessary, and indeed harmful; probably it suffices to change the 'bipped' gauze once in ten days. Occasionally the surgeon may feel justified in closing the cavity entirely after 'bipping' it, but this is not often possible. Other methods of closing the cavity in the bone are alluded to at p. 649.

Ununited Fractures.

Three varieties of ununited fracture have been described: (1) *Absolute non-union*, when no attempt at repair is made, may result from fractures due to the presence of some local disease which has led to

wide destruction of bony tissue, such as sarcoma or osteomalacia, or from the resection of extensive areas of bone for sarcoma or gunshot injuries. (2) *Fibrous union* consists in the development of a more or less firm mass of connective tissue as the bond of union between the ends of the bones, which are either rounded off and closed by a thin plate of bone or cartilage, or are sometimes atrophic and pointed. (3) A *false joint*, or *pseudarthrosis*, is a condition in which the ends of the fragments are covered either by bone or cartilage, and more or less altered in shape, so as to form a shallow ball-and-socket joint, the capsule being represented by the surrounding fibrous tissue, and the synovial cavity by the formation of an adventitious bursa.

The most common situations for ununited fractures are projecting processes of bone to which powerful muscles are attached, such as the patella, olecranon, coracoid process, posterior half of the os calcis, etc.; whilst in long bones the middle of the shaft of the humerus and the upper and lower thirds of the femur are the favourite sites.

Causes.—(1) Want of apposition of the bony ends, owing to extensive resection, or to muscular action, *e.g.* in the patella, when the two fragments are widely separated; (2) the interposition of muscular or aponeurotic tissue, or detached fragments of compact bone; (3) failure of efficient reduction and maintenance of the reduction (in this respect non-union associated with too heavy traction whereby the fractured ends are artificially separated should be noted; removal of the excess weight in these cases will at once promote union); (4) defective blood-supply to one or both fragments, as by injury to the nutrient artery, or as in transcervical fracture of the cervix femoris, where the only source of supply to the upper fragment is a small twig derived from the obturator artery running along the ligamentum teres; (5) local affections of the bone, such as suppuration with necrosis in compound fractures, malignant tumours, or the undue pressure of pads upon newly-formed callus; (6) general bone disease, as osteomalacia; and (7) general constitutional weakness or debility, and diseases such as scurvy or severe syphilis.

The **Signs** of an ununited fracture are usually obvious, mobility between the fragments being easily obtained in some directions, though perhaps not in all; of course, crepitus is absent. It is perfectly possible, however, for a person with good muscular development to have an ununited fracture with but little functional disability; the condition may be obvious when the muscles are relaxed, but disappears when the muscles contract. In doubtful cases radiography will help in diagnosis.

The **Prognosis** is fairly good if suitable treatment is adopted, and the local or general conditions do not prohibit reunion. In particular emphasis must be laid upon the necessity for patience in the non-union associated with infected open fractures. Until all necrosed tissue has been removed, and the infection overcome, reparative processes are often slow in being established. If the parts be fixed, and the vascularity of the limb increased by massage and the use of such portions of the limb as can be moved without displacing the fragments, and if the general health be improved, repair without

operation can often be established in time. Operation itself is not always successful, especially if the soft parts have to be extensively interfered with in order to secure reposition of the fragments; in children, under such circumstances, the outlook is poor, the ends of the bone becoming atrophic, rounded, and covered by cartilage; in such the final resource is not unfrequently amputation.

Treatment.—(1) If in good position, the parts should be refixed, and a course of passive venous congestion carried out. A Bier's elastic bandage is applied to the limb above the fracture for three or four hours daily. Excellent results often follow. At the same time the general health is improved by a stay at the seaside or the administration of tonics, and the condition of the limb improved by massage. If an external support can be arranged so as to enable the patient to use the limb, though the fracture is still ununited, so much the better; it may stimulate the bone-forming power of the fragments.

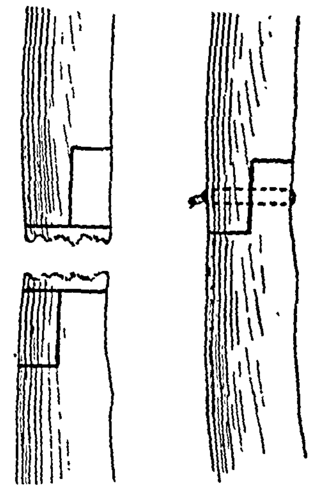


FIG. 273.—'STEPPING' OPERATION FOR UNUNITED FRACTURE.

Having freed the ends of the fragments, a saw cut is carried across the end to make certain that bony tissue is exposed. The saw (possibly a butcher's) is next carried longitudinally up the centre of the shaft to a sufficient distance, and the small fragment loosened by a Gigli saw. The same process is performed on the other fragment, and the wire mattress suture is then introduced through holes previously made. Exact and accurate fitting of the fragments is essential for good results.

(2) Failing this, operative measures must be undertaken. If the bone is tolerably superficial, and the ends not very far apart, they should be exposed, sawn into shape, fitted together, and secured by catgut sutures, silver wire, or pegs. To effect this a free incision in a line of safety is necessary, taking special precautions to protect not only the main nerves, but also their muscular branches. The ends of the bone are carefully examined, and suitably cut into shape so as to secure effective coaptation. One of the simplest and best methods is to cut 'steps' in the bone ends by a saw (Fig. 273) and to fix the fragments by a catgut or wire mattress suture. The limb is shortened somewhat by this means, but firm union is secured, and the delay and doubts associated with bone grafts are avoided. See also below, *re* 'flail-arm.'

(3) If, however, the bones are deeply placed, so that it is difficult to expose the ends and fit them together, it may be wiser to leave them in their bad position, and fix them by the insertion of autogenous bone pegs, or failing this by screws or ivory pegs. Thus, in the upper end of the femur non-union is usually associated with overlapping of the fragments to a considerable extent. To expose and fit these together would necessitate a very extensive dissection; it may be desirable in such cases merely to cut down in front upon

the upper anterior fragment, drill two holes in different directions through both fragments, and into these insert suitable pegs or screws. Two holes should always be employed to prevent slipping of the fragments during the necessary manipulations; whilst one drill is removed for the insertion of the peg, the other holds the bone steady. Their presence causes the formation of a large amount of callus, and by this means the fracture is consolidated. Of course, this procedure involves the persistence of shortening, and in young and healthy adults it is probable that a more extensive operation with complete reduction and fixation of the fracture is advisable; but unless the local and general conditions are good, the above procedure may suffice.

(4) When there is loss of substance between the bone ends and other operative measures fail, various methods of bone-grafting may be employed (p. 686)

(5) Beck has introduced a new method attended with considerable success. Numerous drill-holes are made passing through the adjacent portions of the fractured bone and thus through the area of non-union. Some thirty or so tracks are made with the drill, this being introduced firstly through a small skin incision just above the line of the fracture and then through one placed just below. The drill-holes radiate in all directions through the sclerosed bone from the two primary points of entry. Osteoclastic and osteoblastic activity are stimulated and union results.

The problem as to how to treat the **flail-arm** resulting from the resection of extensive areas of bone for gunshot wounds is one that has recently exercised many surgeons. The condition occurs most frequently at the upper limit of the arm due to removal of the head of the humerus and a good portion of the shaft, or in the neighbourhood of the elbow, the shattered bone ends having been widely exsected. (1) It is necessary to support the limb after the original operation and during convalescence in such a manner as to encourage accommodative shortening of muscles, etc.; to permit the arm to hang without support must obviously result in stretching of these muscles by the weight of the limb. This support should rest on the shoulder above, to which it is carefully fitted, and should grasp the elbow or forearm below. (2) During the period of waiting which must supervene before further operation is feasible, the biceps and triceps must be toned up daily by electrical treatment (sinusoidal current), and encouraged to contract, thereby diminishing the gap between the bone ends. Skilful operative treatment directed towards the bones will prove to be useless unless the muscles have been previously treated in this way; they cannot contract and control distal parts if they are slack. (3) The actual details of operative treatment must vary in different cases, but essentially it consists in approximating the bone ends sufficiently to permit of the introduction of silver wire or a plate, which shall hold the ends together. Thus the lower end of the humerus may be pushed down and wedged into the hollow of the olecranon and there fixed; the upper end of the humerus may be attached to the lower lip of the glenoid cavity, or to the acromion process which has been sawn through and turned down. Occasionally

simple bone grafts will suffice to secure fixity, and sometimes these grafts may include such structures as a complete joint, but our experience is not yet sufficient to justify any dogmatic statement.

Disunited Fracture is the term applied to a rare condition, in which a fracture which had been firmly united becomes separated again. It is only met with when the individual develops some extremely debilitating disease, such as scurvy, and may be recovered from under suitable treatment directed to the cause, and by fixation of the parts.

Vicious Union (Fig. 274) of fractures results either from imperfect adjustment of the ends of the bone, or from the parts not being kept at rest, and hence becoming subsequently displaced. The difficulty of managing serious compound fractures explains the frequency with which vicious union is seen after gunshot wounds. Various kinds of deformity and disfigurement, accompanied or not by loss of function, may result, and, if these are serious, means must be taken to remedy matters. If observed early, when the callus is not too consolidated, it is not difficult forcibly to readjust the parts by manipulation under an anæsthetic—if necessary refracturing the bone. In some cases powerful mechanical appliances, or osteoclasts, are employed for this purpose, but care must be exercised not to damage unduly the soft parts. The *open* method is certainly preferable, cutting down on the bone, redividing it, removing redundant callus, and fixing the fragments by silver wire, pegs, or screws. Of course, after septic gunshot wounds the usual precautions as to delay and preliminary vaccine treatment to protect against infection must be observed.

FIG. 274.—VICIOUS UNION WITH MARKED DEFORMITY AFTER FRACTURE OF FEMUR.

Special Fractures.

Bones of the Face.—The **Nasal** bones are broken as a result of direct violence—by the fist, a cricket-ball, stick, etc. The fracture is generally transverse, and situated just above their free margins; occasionally, when greater force is used, it occurs to the root of the nose, and may then be associated with fracture of the frontal bone or base of the skull (Fig. 275). In young people the cartilages alone may be separated. There is usually considerable deformity from depression or lateral displacement of the fragments, although it may at first be masked by the amount of bruising. Severe epistaxis, surgical emphysema, and cerebral symptoms are sometimes met with as complications. The fracture very readily becomes consolidated, and

the deformity is thus often irremediably fixed, unless its presence is determined at once, and suitable treatment adopted. The **Septum** is sometimes broken and depressed, in association with or apart from the above injury. Lateral displacement occurs, causing unilateral nasal obstruction and some amount of obvious deformity. The **Treatment** of these cases consists in immediate replacement of the bones, advisably under an anæsthetic; this may be accomplished by the pressure of some blunt instrument, such as a pair of dressing forceps, the blades of which, covered with rubber, are introduced within the nostril. A pad of lint or gauze soaked in carbolized oil is, if necessary, inserted to maintain the position, and a gutta-percha or zinc splint moulded to fit the bridge. This dressing should be changed at least every twenty-four hours.

The **Lachrymal** bone has been broken by direct violence, the fracture usually extending from the nasal bone to the lateral mass of the ethmoid. Interference with the flow of tears and surgical emphysema are the two most marked symptoms.

FIG. 275.—FRACTURED NASAL BONES.

The **Malar** bone is but rarely broken without the other bones of the face being involved; fracture is almost always associated with damage to the anterior wall of the antrum and considerable depression of the fragments. An attempt should be made to replace the parts by pressure from within the mouth, but should this fail a small incision should be made in the cheek, a hook inserted, and the depressed bone pulled and levered out into position.

The **Zygoma** is fractured by direct violence applied from without; the broken portion may be depressed below the surface, but vertical displacement is limited by the attachment of the masseter below and of the temporal fascia above. Reposition, either by manipulation from within the mouth, or even by operation, is essential in order to prevent interference with the subsequent mobility of the jaw. Perhaps the simplest plan to adopt is to encircle the zygoma subcutaneously with a loop of silver wire and drag it up to its natural level.

The **Superior Maxilla** is invariably broken as a result of direct injury, such as a blow or gunshot wound; it is almost always compound, and often bilateral. The alveolar portion is either partially or entirely detached, or a transverse fissure, extending as far as

the pterygoid processes on each side, may render the whole palate and lower part of the facial skeleton movable. More frequently all the bones of the face are smashed and comminuted, severe hæmorrhage sometimes resulting from wounds of the terminal branches of the internal maxillary artery. **Treatment** consists in merely keeping the patient quiet and applying cooling lotions; union occurs with great readiness, but is sometimes associated with suppuration and necrosis. The patient must be fed by a tube, and a carefully-fitted dental plate should be applied to a broken alveolus after removal of the teeth which penetrate the affected region.

The **Inferior Maxilla** is usually fractured by direct violence applied from in front, as by a fall or a 'punch' on the chin; more rarely the force acts from the side, and then the bone may break in the middle line. Most frequently, however, the lesion is a little in front of the mental foramen in the neighbourhood of the canine tooth (Fig. 276), this being a weak spot at the junction of two strong parts, *viz.* the symphysis menti and the alveolar process carrying the molar teeth. This fracture is occasionally bilateral—when great violence has been applied to the symphysis. A solution of continuity sometimes occurs close to the last molar tooth (Fig. 277), whilst the coronoid process and condyle have also been broken, the former only as a result of severe direct force, *e.g.* a gunshot wound, the latter from either direct or indirect violence. Gunshot wounds of the lower jaw are often comminuted and associated with gross destruction of the soft tissues, and often with loss of considerable portions of bone.

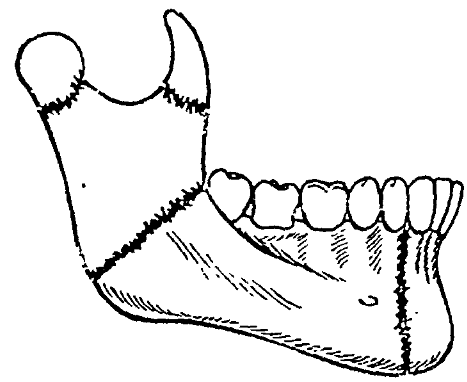


FIG. 276.—LOWER JAW, INDICATING THE MOST COMMON SITES OF FRACTURE.

The **Signs** of fracture are very evident if the lesion is situated anteriorly; but when behind the teeth, diagnosis may be much more difficult, apart from radiography. The usual variety is almost always compound, owing to the firm attachment of the muco-periosteum to the alveolar border. Laceration of the gums, the blood-stained saliva soon becoming fœtid, the irregularity in the line of the teeth, some of which have been knocked out or loosened, and the easily elicited crepitus, all constitute a typical picture. There is often considerable pain, owing mainly to the tearing of the mucous membrane, but possibly due to implication of the inferior dental nerve. The main trunk, however, generally escapes, owing to the position of the fracture in front of the mental foramen, whilst in those behind there is but little displacement. Smart hæmorrhage sometimes occurs from laceration of the accompanying artery. The posterior fragment is usually raised and displaced inwards, whilst the anterior portion is drawn outwards by the preponderating pull of the internal pterygoid. In a bilateral fracture the loose central fragment is displaced downwards

by the causative blow, and held in that position by the muscles, whilst the posterior fragments are drawn upwards and outwards by the temporal and masseter muscles. When situated *at the angle* or *in the vertical ramus*, there is such equal muscular support on the two sides that but little displacement results. When the fracture passes *through the neck of the condyle*, that process is drawn forwards and inwards by the external pterygoid, whilst the body of the bone is freely movable antero-posteriorly and displaced towards the fractured side. When the *coronoid process* is detached, it is dragged upwards by the temporal tendon, but no great displacement can occur, owing to the extensive attachment of the tendinous fibres.

FIG. 277.—FRACTURE OF MANDIBLE.

Treatment.—Every effort must be made from the first to keep the mouth clean and free from infection by the frequent use of mild antiseptic lotions, especially before and after food. The co-operation of a dentist is always essential. Teeth that are merely loosened in their sockets may often be left, and will become refixed; but teeth that are quite loose, and all septic roots, should be removed, as also those sound teeth which obviously encroach on the line of fracture. The lesion is practically always septic, and the laying open of the deeper parts of the alveolus of any tooth involves it in the septic process, and converts it into a septic foreign body which necessarily must be removed. By this practice it is possible that a few teeth which might be saved will be sacrificed, but it is also certain that a great gain in

cleanliness will more than compensate for this by increased rapidity of repair, and decreased likelihood of necrosis and other septic dangers.

The occurrence of serious septic osteitis is indicated by increasing pain and discharge, with inflammatory swelling below and outside the jaw; if need be, external incisions must be made to drain abscesses. Necrosed fragments of the bone ends are absorbed after a time or are separated as sequestra, and during the interval unremitting care as to cleansing the mouth must be maintained.

1. As a temporary measure, and indeed as a permanent appliance in simple cases without displacement of the fragments, a 'barrel' bandage should be applied. This form of bandage is far superior to the four-tail bandage so often advised in first-aid books. About six feet of a two-inch bandage is required. The middle of the bandage is

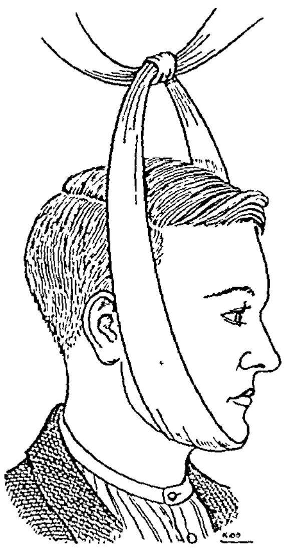


FIG. 278.—FIRST KNOT OF BARREL BANDAGE.

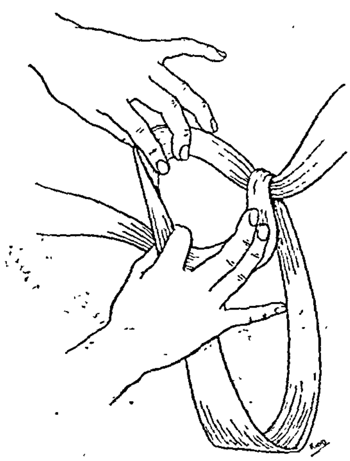


FIG. 279.—OPENING OUT THE KNOT.

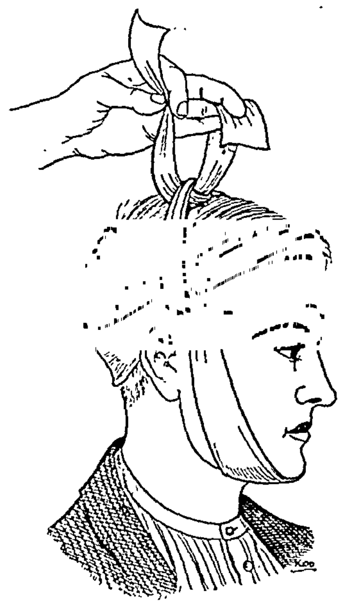


FIG. 280.—THE FINISH OF THE BANDAGE.

placed under the jaw (Fig. 278) and a simple knot is tied over the vertex of the skull. The knot is then opened so that the front loop comes in front of the forehead and the back portion under the occiput (Fig. 279). The two ends of the bandage are then taken and upward tension is exerted, and by a slight adjustment the two running hitches are made to occupy a position slightly above and in front of the ear (Fig. 280). The two ends are then tied in a reef knot on the top of the head. This barrel bandage was first described and used by Sir Harold Gillies and Kelsey Fry in the treatment of war fractures of the lower jaw, and it is now universally used.

2. In all cases where displacement of fragments is present, treatment must be undertaken in collaboration with a skilled dentist. Several different types of appliance to fix the fragments and steady the jaw are available.

The best appliance is *Gunning's interdental splint*, made of non-corrosive metal fitted over the crowns of all the teeth that are left of the lower jaw, only a bar or narrow bridge being present at the site of the fracture; this when fixed in position holds the fragments steadily. It is subsequently united to a similar splint fitted to the upper jaw, thereby securing complete rest to the mandible. The mouth remains a little open, and a gap between the two splints in the middle line or corresponding to the fracture provides for feeding and irrigation. In the absence of sepsis union takes place readily in about five or six weeks.

A modification of this plan is available for cases where the jaw is edentulous or has no teeth suitable for fixation purposes. A vulcanite splint should then be provided, fitting over both alveolar ridges in the same way as an ordinary plate, and taking support from any teeth in the maxilla that may happen to be present. It is held in position

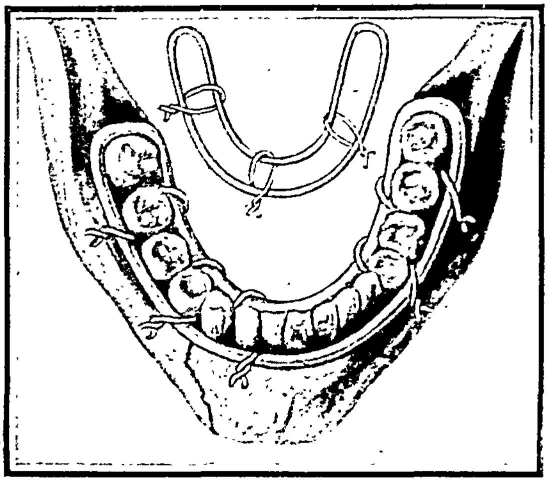


FIG. 281.—HAMMOND'S SPLINT FOR FRACTURE OF LOWER JAW.

by a four-tailed bandage, and is removable for cleansing purposes. Though an ideal result cannot be expected from such treatment, yet it will limit displacement and give comfort. Perhaps at a later date, when the parts are clean, it may be possible to fix the fragments by a metal or bone plate applied on the lower border of the bone through an external incision.

A less satisfactory method of treatment, but one that will suffice in many of the simpler cases, is the **Hammond wire splint.** It consists of a stout wire collar or framework (Fig. 281), which encircles the whole series of teeth. It is accurately fitted by a dentist, firstly to a plaster cast, subsequently to the jaw itself, and is fixed by passing wires from one half to the other between the teeth.

The presence of a second fracture makes fixation much more difficult, but emphasizes the necessity for the assistance of a dentist, who alone can fit the intrabuccal splint necessary in such a case.

Slight loss of substance of the maxilla makes no difference in the

principles of treatment. Every effort is made to clean the parts, and the fragments are brought into the best apposition possible by the interdental splint, and there allowed to unite, even if one half of the jaw is thereby displaced to one side for a time.

Gross loss of substance, such as has frequently occurred after gunshot wounds, can be made good by grafting, and the skill which has restored some of the unfortunate victims of these wounds to something like respectable appearance has been most remarkable and gratifying.

Ununited fractures of the mandible are not very uncommon. The patient must wait until all sepsis has disappeared and the wound in the mouth is healed, and then external operation holds out a good chance of repair. The fracture may be wired, plated, or fixed by a bone graft.

Fracture of the Hyoid Bone is uncommon, arising usually from direct violence such as a forcible grasp or the constriction of the neck in hanging. Either the body may be broken, or one of the cornua separated. The symptoms produced are: Pain on attempting to move the tongue, jaw, or neck; a husky voice, and deformity, which can sometimes be detected from without. Occasionally the mucous membrane is perforated, and bleeding into the pharynx may occur, whilst œdema of the glottis may supervene. The fragments should be approximated as well as possible by manipulation between one finger in the mouth and the hand outside, and the neck then fixed by a poroplastic collar.

Fracture of the Ribs may arise in two distinct ways: (1) By *direct violence*, as by blows or stabs, the fragments being driven inwards, and damage to the underlying pleura, lungs, liver, or diaphragm being very likely to occur. Compound fractures due to penetrating wounds are not very common apart from military surgery; they are serious accidents as introducing the septic element, and possibly determining pulmonary collapse. (2) Much more frequently they are caused by *indirect violence*, as when the chest is compressed between a cartwheel and the ground, or between a wall and the back of a waggon. The ends of the ribs are then approximated beyond the limits of natural elasticity, and they give way at the most convex part, *i.e.* near the angle. The viscera may be contused, but less often than in the former class, although hæmothorax from rupture of the parietal pleura is not uncommon. As a rule more than one rib is broken, but the displacement is rarely marked, except in cases due to direct violence, where several ribs have been 'staved in.' The fifth to the eighth ribs are those usually injured, being more prominent and fixed at both ends; the first and second ribs are so well protected by the clavicle as to be seldom broken by direct injury, although great violence from above downwards to the outer end of the clavicle may lead to such an accident; the lower ribs often escape on account of their greater mobility. Elderly women and persons suffering from various mental diseases, such as general paralysis, are specially prone to this fracture.

The **Symptoms** are tolerably obvious, *viz.* a sensation of something snapping or giving way, a sharp localized catching pain at the site of

the injury, increased on deep breathing and coughing, and possibly some local extravasation and swelling. Pain is elicited by a local examination, and also by conjoined pressure upon the sternum and spinal column, whilst the fracture may be evident on palpation, or crepitus detected when the patient coughs or on auscultation. When several ribs are driven in, a marked depression results, but if a single bone is broken in a fat individual, the diagnosis may be extremely obscure. The clinical history and treatment of the pulmonary or pleural complications, as also of penetrating wounds, associated with compound fractures, are discussed elsewhere.

Treatment.—The affected side should be firmly strapped with broad strips of adhesive plaster, so as to limit its movements. The strips, $1\frac{1}{2}$ to 2 inches wide, should extend beyond the middle line, both front and back, and are applied from below upwards, whilst the chest is in a state of forcible expiration, each strip overlapping the preceding one and crossing the direction of the ribs (Fig. 282). A firm woollen bandage should then be applied over all. If the ends of the bone are driven inwards, strapping can rarely be borne, as it tends still further to irritate or compress the lung. Under such circumstances all constriction of the chest must be avoided, the patient being confined to bed with a sandbag between the shoulders, and the arm bound to the side. When the lower ribs are broken, tight applications are generally contra-indicated, since the diaphragm is likely to be irritated, and troublesome hiccough may result. Ribs unite readily, but with a considerable amount of callus, owing to the mobility of the fragments.

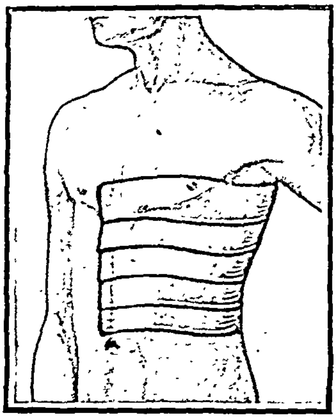


FIG. 282.—METHOD OF STRAPPING BROKEN RIBS.

Separation of a Costal Cartilage sometimes occurs, giving rise to similar symptoms and requiring the same treatment as a broken rib. Occasionally the cartilage itself may be fractured. In each case the resulting bond of union is osseous.

Fracture of the Sternum is almost always due to direct violence, but is occasionally caused by forcible flexion of the body, and is then generally associated with fracture of the spine. The line of fracture is usually transverse, the bone giving way either between the manubrium and gladiolus or a little below this level. The fragments may remain *in situ* or the upper portion be displaced backwards, the deformity in such cases being very evident, and great dyspnœa resulting. As a late effect, aneurism of the arch of the aorta may occur. **Treatment.**—The patient should be kept in bed with a pillow between the shoulders, and the chest strapped as for fractured ribs. If the patient cannot bear this portion, he should be allowed to sit up with the body leaning forwards. Reposition can sometimes be effected by manipulation and extension, but the possible co-existence of a fractured spine must not be overlooked.

Fractures of the Upper Extremity.

Fracture of the Clavicle.—No bone in the body, with the exception of the radius, is broken more frequently than the clavicle; this is due to its exposed position and its buttress-like action in keeping out the point of the shoulder, so that every shock to the arm is transmitted through it to the trunk. Although sometimes broken by direct violence, fracture is usually due to force directed to the hand or shoulder, and hence is common in falls from horseback, and occurs frequently in jockeys, on the hunting-field, or amongst recruits in mounted corps. It is more common in men than in women, and in children is often of a green-stick nature. The bone may yield in four different situations, *viz.*:

1. **At the Sternal End,** an unusual occurrence, due to direct or indirect violence. The displacement varies with the line of fracture; if transverse, it is slight; but if oblique—and this is most usual—the outer fragment is drawn downwards and forwards as in the next variety, though to a less degree.

2. **Through the Greater Convexity,** the commonest situation. The bone yields about its centre, or a little external to it, and the line of fracture is slightly oblique, running from before backwards, downwards, and inwards. The displacement is quite characteristic, and is present in any fracture situated between the rhomboid ligament on the inner side and the coraco-clavicular ligaments on the outer, being less marked, however, when the fracture is nearer the extremities than in the centre of this space. The patient gives a history of injury and severe pain, and supports the elbow with the other hand, the head being bent over to the affected side to relax the muscles of the neck; the arm is powerless. The point of the shoulder is less prominent than usual, being approximated to the middle line, and on a lower level than the other, whilst at the site of fracture the inner fragment projects. This deformity is accounted for by a displacement of the whole outer fragment downwards, forwards, and inwards (Fig. 283), the outer end being, however, more displaced than the inner. This is mainly due to the weight of the arm acting upon the outer fragment when the buttress-like action of the bone is gone; muscular action has but little effect. The position of the inner fragment is probably but little altered, since it is held in place by the rhomboid ligament; the apparent projection of its outer end is mainly due to the depression of the outer fragment.

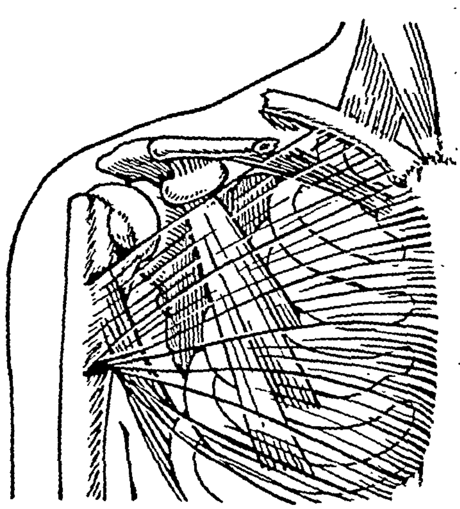


Fig. 283.—Fracture of Clavicle through Greater Convexity.

3. **Between the Coraco-clavicular Ligaments,** usually arising from

direct violence, and with but little displacement, owing to the tension of the ligaments and to the fact that the periosteum is not torn across. The signs of local trauma and crepitus are, however, present, though not very obvious.

4. **At the Acromial End,** external to the trapezoid ligament, and, again, generally produced by direct violence. The inner fragment retains its position unaltered, but the outer fragment is dragged down by the weight of the arm, and forwards by the action of the muscles, so that it sometimes lies at right angles to the rest of the bone.

Complications arise most frequently in cases produced by direct violence. The subclavian vein may be injured, or the brachial plexus; and even the dome of the pleura and the subjacent lung have been wounded. Gangrene of the arm has been caused by obstruction to the vessels. Great violence has resulted in fracture of the first rib. Excess of callus in repair not unfrequently leads to nerve pressure, which for its relief may require operation.

Treatment.—Where there is little or no displacement, all that is needed is to immobilize the arm in a sling and to keep the patient quiet. In a green-stick fracture, the deformity can be remedied by manipulation, and the arm bandaged to the side.

In fractures with displacement the deformity is as a rule easily remedied by drawing the points of the shoulder upwards and backwards, a knee between the scapulæ being used for counter-pressure and steadying of the patient. All that is required subsequently is to maintain this position for a time.

As an emergency measure the *three-handkerchief plan* can be employed. Two large handkerchiefs, folded double and rolled into bands, are placed vertically, one over each shoulder, and under each axilla; each is lightly knotted behind, and the ends firmly tied to the opposite handkerchief across the middle line. By this means the point of the shoulder is kept outwards and backwards. The third handkerchief is used as a sling, the elbow being kept forwards and the hand placed over the sound clavicle.

The simplest method of fixing the fracture in a young patient who is not too fat is by the use of a broad strip of *strapping* over the site of fracture so as to grip both fragments. If the right clavicle is broken, one end of the strapping is applied to the left side of the umbilicus and carried up over the chest wall to the clavicle, and thence over the shoulder and down the back to end on the left side of the body below the scapula. A folded pad of strapping several layers thick, and with the adhesive side out, may be moulded over the site of the fracture with advantage before the main strip is applied. Fixation thus being effected, the arm is supported in a sling for ten days or so, and then massage and movements of the shoulder are commenced. Some slight deformity may occur, but that is not of great importance, granting that the mobility of the arm is early restored. At Newmarket, where this plan has been largely used for jockeys, the patients are allowed to ride in about a fortnight.

In ladies, where even the slightest deformity is undesirable, it is better to confine them to bed for three weeks; the head is kept low

without a pillow, and a sandbag placed between the scapulæ, the arm being bandaged to the side.

In children, one of the best plans of treatment is that suggested by Hey Groves. A straight splint is placed horizontally behind the shoulders, and a figure-of-8 bandage round the shoulders and splint, and crossing in front, draws the shoulders back and remedies the displacement. This is kept in position for three or four weeks, and necessitates the child lying on its back at night (Fig. 284).

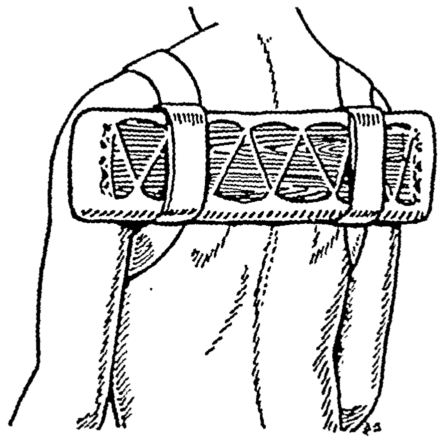
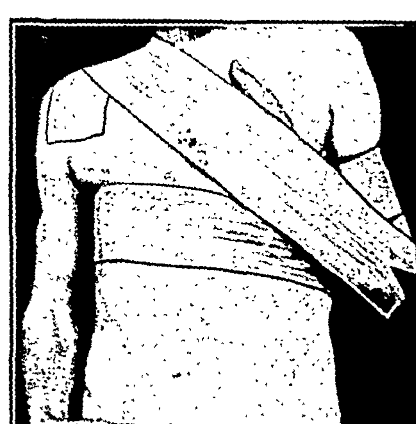


FIG. 284.—HEY GROVES' METHOD OF TREATING A FRACTURED CLAVICLE.

Less satisfactory is the old-fashioned **Sayre's Method.** A long strip of adhesive plaster, 3½ inches wide or less, is passed round the arm a little below the axilla as a loop, with the sticky side out, and then around the body with the adhesive side inwards, the arm being drawn well back, and the loop and end secured by stitches (Fig. 285). If this has been applied firmly, it may now be used as a fulcrum, so that as the elbow is drawn forwards the point of the shoulder is directed backwards and outwards, and thus the main deformity is overcome. Another strip of a similar width is applied over the elbow (a small hole being cut to receive the point of the olecranon), and by this means the elbow is raised and drawn forwards (Fig. 286), so that the hand can be placed on the opposite shoulder, and the desired position is thus maintained. Probably more than one strip of plaster will be needed in order to secure the arm, whilst an additional bandage is also useful. There is no need to maintain this position for more than ten to fourteen days, as massage and movements must then be employed to prevent stiffness; in the intervals of exercises or at night the arm may be bound to the side to avoid accidents, but daily movements must be practised.



FIGS. 285 AND 286.—SAYRE'S METHOD OF STRAPPING FOR FRACTURED CLAVICLE.

Ununited fractures are uncommon, but they occur and may require fixation by operation. Vicious union is not rare, but seldom needs treatment.

Fractures of the Scapula.—1. The **Acromion Process** may be broken by direct violence applied to the point of the shoulder. The arm hangs powerless, supported by the other hand, and the shoulder is flattened. The irregularity of the bone can be readily detected, and crepitus can be elicited by raising the elbow and rotating the arm. Occasionally the tip alone is detached, and then the above signs will not be present. **Treatment** consists in raising the elbow, and bandaging the arm to the side.

FIG. 287.—FRACTURES OF THE NECK OF THE SCAPULA.

A, Through the glenoid fossa; B, through the anatomical neck; C, through the surgical neck.

2. The **Coracoid Process** is rarely fractured, and then only by direct violence. There is but little displacement, on account of the powerful ligaments attached to it, and no treatment is needed except to raise the elbow by a sling and keep the arm to the side.

3. The **Body** of the scapula is broken as a result of considerable direct violence, which is often primarily received by the spine. There is but little displacement when the fracture is comminuted or transverse just below the spine. A longitudinal fracture may, however, result in the inner or vertebral fragment being drawn upwards and outwards in front of the axillary portion by the serratus magnus and levator anguli scapulæ. The diagnosis is sometimes difficult owing to the presence of a large hæmatoma, but can usually be made by detecting crepitus on grasping the bone firmly, and moving one fragment on the other, or by radiography. **Treatment** consists in bandaging the arm to the side, and possibly applying strapping to support the fragments.

4. Fracture of the **Neck** is usually due to great violence directed to the shoulder, but is uncommon. A portion of the articular surface is broken off and displaced downwards in some few cases of dislocated shoulder (Fig. 287, A); or the fracture has been known to run through the anatomical neck (Fig. 287, B), either condition causing some flattening of the shoulder, slight lengthening of the arm, and displacement downwards of the head of the humerus, so that the appearance

somewhat resembles that of a dislocation. **Treatment.**—The arm must be kept to the side and raised.

More commonly, however, the fracture involves the **Surgical Neck** (Fig. 287, C), extending from the suprascapular notch above to just below the origin of the triceps muscle, so that the detached fragment includes the coracoid process. Flattening of the shoulder results, with prominence of the acromion, lengthening of the arm as measured from the acromion to the external condyle, and crepitus on raising and rotating the limb. **Treatment.**—The bone is replaced by pressure in the axilla, if necessary under chloroform, and fixed by an axillary pad or a ∩-shaped leather splint, whilst the arm is kept to the side.

Fractures of the Upper End of the Humerus—1. Of the Anatomical Neck.—They should be differentiated into those associated with adduction of the lower fragment and those, much less common, accompanied by abduction. They are usually due to blows or falls on the shoulder, less commonly to indirect violence, and occur more often in elderly people than in the young. The shoulder becomes greatly swollen from effusion of blood; pain on movement is severe, but crepitus may perhaps be felt on rotating the arm; there is usually about half an inch of shortening. In most cases the upper fragment is not totally detached, but remains connected with the rest of the bone by a few shreds of capsule, and thus necrosis is prevented; it is sometimes impacted into the lower fragment, and marked deformity of the head of the bone results, which can be detected occasionally by palpation from the axilla. If it is completely detached, the small upper fragment is often rotated on its own axis, and even dislocated into the axilla. Distinction between these fractures and a dislocation of the shoulder-joint is sometimes difficult, especially where bruising and swelling obscure normal landmarks. X-ray will of course confirm the diagnosis one way or the other, and the shortening of the arm when measurement is taken from the acromion process to the olecranon, the presence of the head in the normal position, and the absence of any depression just below the acromion process should serve as diagnostic points.

Treatment.—It has been customary in the past to treat these fractures by binding the limb to the chest wall and supporting the arm in a sling. Early massage about the fourth or fifth day is commenced and passive movements instituted a few days later. Active movements are encouraged from about the tenth day, and union is completed after some six weeks. These cases, however, are always accompanied by a certain amount of subsequent arthritis in the joint, and in addition movements are never full, especially as regards abduction. The reason for this is obvious in that all essential factors for obtaining a good result in the treatment of a fracture—namely, good reduction of displacement and the maintenance of that reduction—have not been employed. The small upper fragment is externally rotated and abducted, and on account of its smallness it cannot be manipulated into alinement with the lower fragment, so that the latter must be brought into apposition with the former. If the arm is abducted, rotated externally 90°, and brought forward slightly in front of the frontal

plane, efficient reduction by traction will enable good position to be obtained.

Abduction splints are not used as often as they should be, on account of the reported difficulty in maintaining them in position. But if they are well padded, and if, after the straps have been tied, some over the opposite shoulder and a second round the chest, fixation is further maintained by turns of plaster-of-Paris bandage, few patients complain of any discomfort and most remark on the complete absence of pain.

In the case of adduction fracture, *i.e.* those in which the lower fragment is adducted towards the chest wall, traction to reduce any overlap displacement is exerted after the arm is abducted; but where abduction exists traction is better applied before the arm is raised. In some cases it will be necessary to exert continuous traction, and this may be done by applying zinc oxide strapping to the inner and outer aspects of the arm, fixing the ends of the strapping to a spreader and attaching this to the outer end of the splint by means of a length of cord. Movements of the wrist and fingers are instituted from the commencement, and after about four days the elbow-joint is moved daily, the forearm being supported throughout so that no displacement of the fractured surfaces shall occur. After about three weeks the traction can be removed and movements of the shoulder commenced gently. Not until the patient is able to raise the arm actively to about 140° is the abduction splint removed.

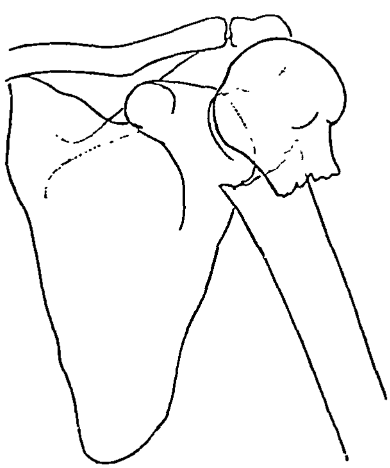


FIG. 288.—FRACTURE OF SURGICAL NECK OF HUMERUS, SHOWING THAT THE UPPER FRAGMENT CONTAINS BOTH TUBEROSITIES.

A word should be said about anæsthesia in these patients. Although in this country local anæsthesia is not popular, it will be found that the application of an abduction splint is rendered far easier with a conscious patient, and in view of this we recommend the employment of local anæsthesia. Injection into the site of the fracture of some 20 c.c. of 2 per cent. novocain gives absolute relief from pain and therefore adequate relaxation.

This method of treatment by abduction is unsuitable in very fat patients or in those who are subject to bronchitis or other chest trouble, and in these the older method should be employed.

2. **Fractures through the Surgical Neck.**—The bone yields in this case below the muscles attached to the tuberosities, but above or through the insertions into the bicipital groove and its margins of the latissimus dorsi, pectoralis major, and teres major. The displacement of the upper fragment varies somewhat, and is often not very great, but in other cases it is abducted considerably. The lower fragment is drawn inwards by the muscles attached to the bicipital

groove, and upwards by the deltoid, coraco-brachialis, biceps, and triceps (Fig. 288). The appearance of the patient is sufficiently characteristic; the head of the bone is still in the glenoid cavity, so that there is no loss of the fulness of the shoulder (Fig. 289), although there is a depression just below unless it is obliterated by the extensive hæmorrhagic effusion.

Treatment.—These fractures should be treated in an abduction splint (*vide supra*).

Should the fracture be very oblique and the upper end of the lower fragment project much upwards and inwards, reduction may be very difficult and the pressure on nerves and vessels severe. In such cases open operation is often desirable. An incision is made along the anterior border of the deltoid, which is separated from the great pectoral, and thereby the anterior surface of the bone is exposed.

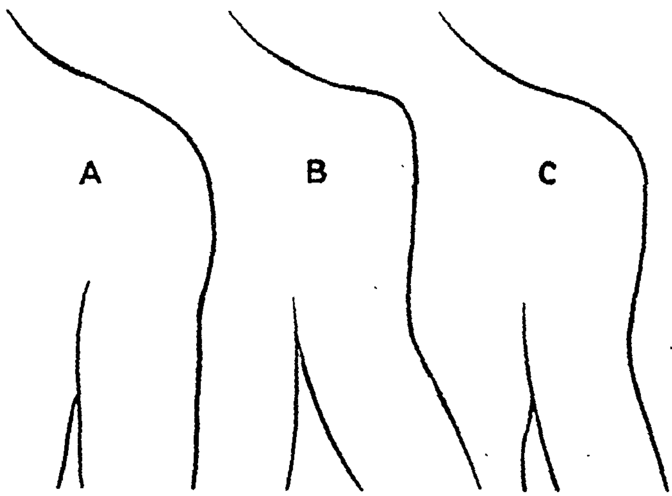


FIG. 289.—OUTLINES OF SHOULDER.

A, Normal shoulder; B, dislocation of the shoulder; C, fracture of surgical neck of humerus.

This will often suffice to enable the ends of the fragments to be freed and brought into apposition, fixation being secured by wire, bone-peg, or a suitably curved narrow plate. If more exposure is needed, the incision is carried upwards and outwards, so as to enable the anterior portion of the deltoid to be divided about one inch below the acromion process and turned downwards and backwards, thereby bringing into view the outer aspect of the head. The muscle is subsequently sutured carefully, and its function is not thereby impaired.

3. Where the *Greater Tuberosity* has been torn off either by muscular action, by direct trauma or in association with dislocation of the head of the humerus, or with fracture through its upper part, apposition can be effected non-operatively only by using an abduction splint in the manner indicated above.

4. **Separation of the Upper Epiphysis** occurs up to the age of eighteen to twenty years, and involves the head and both the tuberosities (see

Fig. 294). The upper end of the shaft is somewhat conical in shape, the apex of the cone fitting into a depression in the middle of the epiphysis (Fig. 290). The lesion usually follows the line of the cartilage; but the displacement is often incomplete, partly from the conical projection hitching against the inner edge of the epiphysis (a doubtful occurrence), but mainly from the persistence of a well-marked periosteal sleeve or bridge on the outer and posterior side. The shaft usually travels forwards, its upper end projecting so as to be felt or even seen beneath the skin an inch or more below the coracoid process; occasionally a well-marked inward displacement is superadded, so that the condition somewhat resembles a subcoracoid dislocation. The presence of the head of the bone in the glenoid cavity should prevent this mistake, whilst the softness of the crepitus distinguishes it from a fracture.

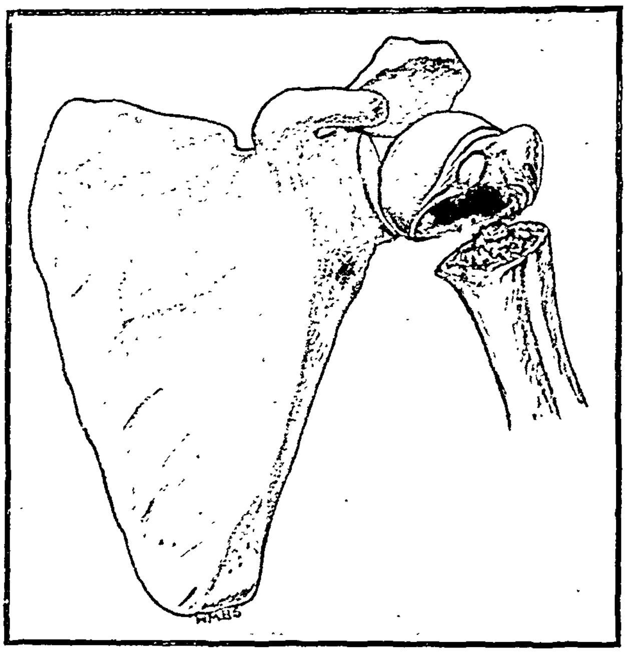


FIG. 290.—SEPARATION OF THE UPPER EPIPHYSIS OF THE HUMERUS.

Treatment. — It is most important to reduce this displacement, since otherwise interference with the growth of the limb is almost certain to ensue. This may be effected by traction upon the arm under an anæsthetic, assisted perhaps by slight rotary movements or abduction; but should these manœuvres not be successful, operation should be undertaken to restore the parts to their correct position by enlarging the hole in the periosteal sleeve. After reduction the limb is treated as for a fracture of the neck. Should union occur in the displaced position, considerable limitation of movement results from the projecting edge of the diaphysis; this may be improved by cutting down and chiselling it away.

5. **Fracture of the Upper End of the Humerus combined with Dislocation** of the head of the bone is not a very common accident. The fracture is generally more or less oblique, and passes through the greater tuberosity or involves the surgical neck.

It is produced by severe direct violence, as by a person pitching with great force on the shoulder. The head of the bone is first forced into the axilla through a rent in the capsule, the tendons attached to the tuberosities being stretched or torn, and the fracture of the neck

follows. Unless seen early, hæmorrhagic effusion makes diagnosis difficult and almost impossible, apart from stereoscopic radiography. If unreduced, the displaced head of the bone may remain loose, or union may occur with much deformity, and the production of many adhesions, which may involve the vessels and nerves, and lead to serious after-trouble in the limb.

Treatment.—Attempts should be made to reduce the dislocation, steady traction being exerted on the abducted arm by an assistant while pressure is made by the surgeon over the head of the humerus in an endeavour to force it back in position. Often, however, the traction will be found insufficient, and in these cases resort to Böhler's traction apparatus will be found very valuable. It consists essentially of an abduction splint with a long thumbscrew running through the transverse limb at its outer part. This screw is fitted with a hook on that end of it which is within the splint. A Steinman's pin or a Kirschner wire is passed through the olecranon process of the ulna, and after a suitable stirrup has been applied this is attached to the hook of the screw by cord. As the screw is turned so will traction be exerted on the humerus, usually to such an extent that a sufficient gap between the upper end of the lower fragment and the glenoid fossa is produced to enable easy replacement of the dislocated head. The after-treatment will be similar to that previously described. Rarely open operation will be required, and the employment of the traction apparatus during reduction is of value.

Fractures of the Shaft of the Humerus may arise from any form of violence, whether direct or indirect, and even from muscular violence, as, *e.g.*, in throwing a cricket-ball. The signs of the injury are very obvious and most typical. The displacement depends largely on the position of the fracture. If it occurs *above* the insertion of the deltoid, but below or through that of the muscles inserted into or around the bicipital groove, the upper fragment is drawn inwards, and the lower upwards and outwards. If, however, it is *below* the deltoid, the upper fragment is drawn outwards, and the lower upwards and inwards. As the line of fracture approaches the elbow, the displacement tends to become more antero-posterior than lateral, owing to the change in shape of the bone. The most common complication is injury to the musculo-spiral nerve which winds round the shaft, and even if unwounded at the time of the accident, it is liable to be involved in the callus.

Treatment.—Reduction of the deformity is usually effected without much difficulty by traction on the forearm with the elbow bent to a right angle, and manipulation. In the simplest cases without displacement the arm is fixed to the chest wall, the most perfect means of immobilizing the limb. In all cases the forearm should be kept in full supination and directed a little forwards at an angle of about 25 degrees to the plane of the anterior chest wall, thereby avoiding internal rotation of the lower fragment.

In cases where the displacement is easily corrected and there is no great tendency to recurrence, the simplest method of fixation is by means of a plaster-of-Paris splint. This is best applied in the form of

a plaster slab which extends from the acromion process, down the outer side of the arm, round the elbow, and up the inner side into the axilla. It is held in place by a few turns of plaster bandage.

Fixation must be maintained for four weeks or more, but from early days full movements of the wrist and fingers are allowed, and also of the radio-ulnar joints.

When the fracture is oblique or comminuted, prolonged extension is often necessary in order to maintain the fragments in good position, and the patient must be put to bed if abduction is also required. Weight extension over a pulley may be utilized, the fixative adhesive plaster taking its pull from the elbow to the fold of the axilla; short splints are applied to support the limb. Perhaps more satisfactory

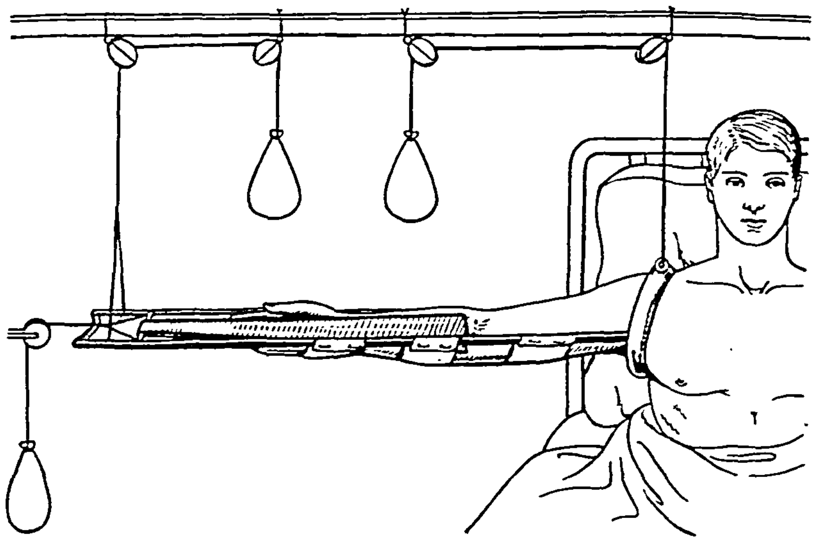


FIG. 291.—THOMAS'S SPLINT APPLIED FOR FRACTURE OF HUMERUS REQUIRING EXTENSION, ABDUCTION, AND SUSPENSION.

The hand is in full supination, and the ring of the splint kept in position by a counterpoising weight. Extension is effected by a weight, the end of which is attached to the extension strapping or glued-on bandage, which reaches to the elbow. Of course a complete trough is required; only three flannel bands are depicted here, and short splints and bandages are omitted.

for this purpose is the short Thomas's splint, the well-padded ring of which takes its purchase from the axilla and chest wall (Fig. 291). Extension is effected by fixation to the splint, or by traction with a weight; the forearm is placed in full supination. The limb, of course, lies in a flannel trough, and if need be short arm splints are added to assist in correcting deformity. The splint with the arm is slung from a suitable overhead support, or otherwise kept from contact with the bed. Consolidation of the fracture, if closed, may be expected in three to five weeks. One objection to the Thomas splint for fractures of the arm is that the elbow is liable to become stiff. This can be prevented if at the end of seven to ten days passive movement of the elbow (including pronation and supination) is undertaken once a day,

the arm being, of course, firmly supported. Another difficulty lies in the restoration of the carrying angle, which is liable to be lost unless the lower end of the humerus is drawn inwards slightly towards the inner bar of the splint.

In cases where prolonged extension is necessary, but abduction is not required, one of the many flexed-arm splints now available should be employed. Of these, Robert Jones's modification of Thomas's splint (Fig. 292) is perhaps the best; the ends of the plaster extension straps are tied to the cross-pieces that project below the elbow, or may be connected with a spring or elastic tractor, and short lateral splints may be added. The rules as to the position and movements of the forearm indicated above must also be followed.

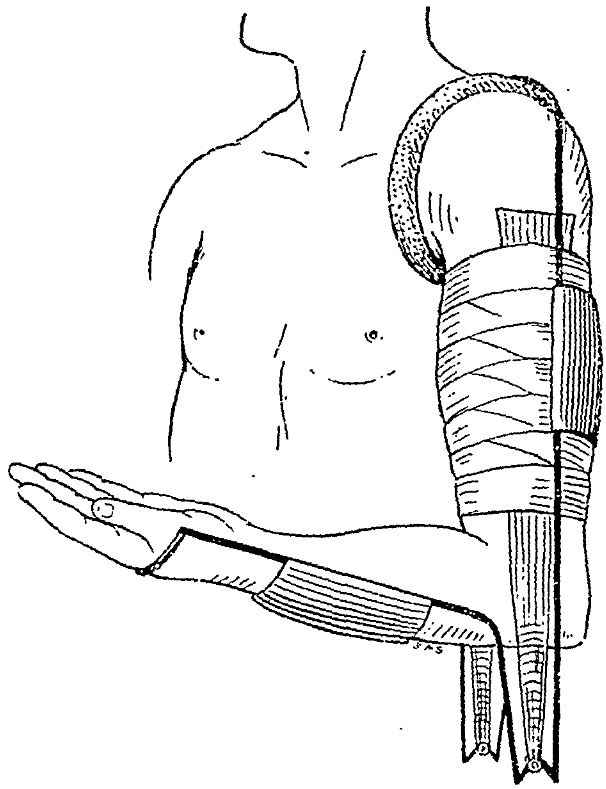


FIG. 292.—FLEXED-ARM SPLINT (ROBERT JONES) APPLIED FOR FRACTURED HUMERUS REQUIRING EXTENSION WITH THE ELBOW FLEXED.

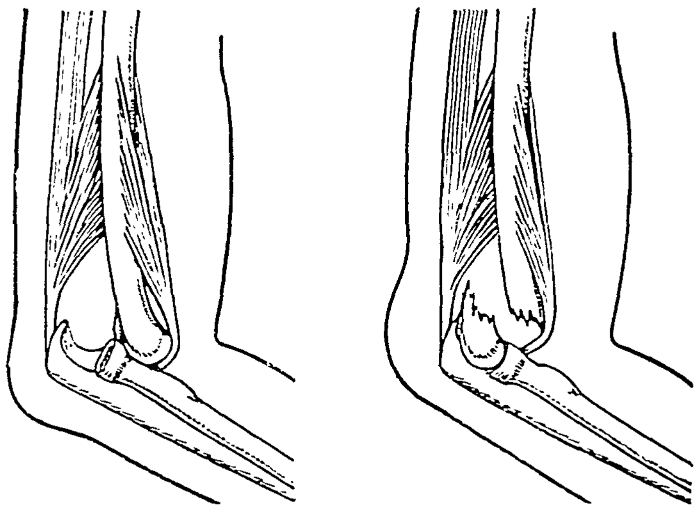
Open fractures are treated on one of these two latter splints, perhaps for choice the Thomas, inasmuch as thereby easier approach can be secured to the wounds. Where extensive sepsis is present, and the treatment may have to be prolonged, stiffness of the elbow is very apt to follow unless early mobilization is undertaken. When the wounds are so placed as to hinder the application of strips of plaster, extension should be exerted through a pin or wire passed through the olecranon process of the ulna.

Operation for the fixation of a fracture of the shaft of the humerus should not often be needed, and, of course, is undertaken only for closed fractures or for open ones where asepsis of the wound is assured. The bone is best approached from the outer side of the biceps, between it and the deltoid, or triceps; the position of the musculo-spiral nerve must always be kept in mind. Wiring is usually difficult, and plating is the best means to adopt.

Ununited Fracture occurs not unfrequently in the humerus, and is probably due to the fact that the necessity for fixing and supporting the elbow-joint has not been appreciated, the forearm being allowed to hang loose on the false plea of tending to diminish the shortening.

It also follows compound fractures where much bone has been removed or destroyed. More perfect fixation and improvement of the general health may cure it; otherwise operative treatment may have to be undertaken.

Fractures of the Lower End of the Humerus.—1. **Transverse Supracondyloid Fracture,** involving the shaft about 1 or 2 inches above the joint, is due either to a fall on the hand with the arm bent, when the lower fragment is usually displaced backwards, or much less commonly to a fall on or violence directed to the point of the elbow, when the displacement is either forwards or backwards. When the lower fragment is displaced backwards, it is also drawn up by the action of the triceps upon the olecranon, a certain amount of angular as well as vertical deformity being thus produced; when displaced forwards, apparent lengthening of the forearm results, with a loss of prominence



A B

FIG. 293.—FRACTURE OF LOWER END OF HUMERUS (B) COMPARED WITH DISLOCATION OF RADIUS AND ULNA BACKWARDS AT ELBOW (A).

of the olecranon. The former of these conditions is likely to be mistaken for a dislocation of both bones backwards at the elbow (*cf.* Fig. 293, A and B), but may be recognized by the following facts: (*a*) The relative position of the bony points at the elbow is unimpaired; in a dislocation they are necessarily disturbed. (*b*) The length of the arm measured from the deltoid tubercle, which can be easily felt at the back of the acromion, to the outer condyle is diminished in a fracture, but remains unaltered in a dislocation. On the other hand, the length of the forearm, as measured from the external condyle to the styloid process of the radius, is shortened in a dislocation, but remains unaltered in a fracture. (*c*) The forward projection of the lower end of the upper fragment is felt above the crease of the joint, whilst in a dislocation it corresponds with it. (*d*) The deformity is easily reduced with crepitus, but readily reappears; in a dislocation the bones are replaced with difficulty, but after replacement they

usually remain in position. Lateral deviation sometimes occurs, and the restoration of the normal 'carrying angle' must always be aimed at. It may be difficult and at times almost impossible to recognize this condition at once, owing to the amount of swelling and ecchymosis present, and therefore a radiographic examination of all serious elbow injuries is essential. Delay in order to permit of the reduction of the swelling is liable to be followed by serious consequences.

Treatment.—Reduction is produced by flexing the forearm in the position of mid-pronation to a right angle and exerting traction on this while the displaced fracture is moulded into position. One of two methods is then advised for maintaining the reduction. A plaster slab round the elbow and extending from the olecranon process to the axilla is applied as in fractures of the shaft of the humerus, and is maintained in position by a few turns of bandage. A further slab, while extension is still being maintained by an assistant, is applied, extending on the outer side of the arm and forearm from the knuckles to the shoulder, it also being fixed by a few turns of bandage. When the plaster has set, the arm is preferably supported in an abduction splint, but can be supported in a sling. If there is any tendency for the deformity to recur, traction can be exerted by strapping applied to the plaster cast. The plaster is kept on for some four to six weeks. Although in this method there is immobilization of the elbow-joint for some considerable time, this is desirable, as if early movement is instituted ossification in the brachialis anticus muscle is very liable to occur.

Alternatively the arm may be fixed by a figure-of-eight bandage extending between the arm and forearm in a sling in a position of flexion for a similar period of time. At the end of about four weeks the flexion is gradually reduced, and by six weeks the patient is allowed to discard the sling altogether. The somewhat stiff elbow is gradually mobilized by physical treatment, and in addition the effect of gravity is to encourage complete extension.

If in either of these methods there is more than a minimum of swelling in the fingers or wrist, *the plaster or bandage should at once be removed* in order to relieve any pressure caused by reactionary bleeding and œdema around the site of the fracture, and until this subsides reduction of the fracture cannot be repeated.

In rare cases where reduction of the fracture is exceedingly difficult this may be effected by traction exerted through a wire or pin placed through the olecranon process the stirrup of which has been connected to Böhler's screw traction apparatus.

2. **T- or Y-shaped Fractures** usually occur as a result of direct injury In a T-shaped fracture a longitudinal fissure extends into the joint through the centre of the lower fragment of a supracondyloid fracture; in a Y-shaped fracture the fissure starts at the articular line and bifurcates above so as to detach both condyles. Sometimes the fragments are not completely detached, and then, although there is much bruising and pain, crepitus is not obtainable; at other times the condyles are separated completely and will move on each other with crepitus, the elbow being increased in breadth. Displacement of the

forearm laterally (usually outwards) often accompanies this lesion. Great swelling and ecchymosis are rapidly developed, and diagnosis apart from radiography is often difficult. If there is no separation of the fragments, **treatment** as for the transverse supracondyloid fracture suffices; but when they are completely detached, attempts to replace the fragments are usually unsuccessful, and it may be wise to operate in order to remove the blood and enable the fragments to be manipulated into position and fixed there by screws, wires, plates, or bolts, but not unless complete asepsis is assured.

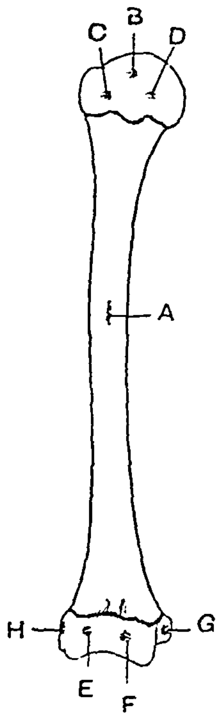


FIG. 294.—CENTRES OF OSSIFICATION OF THE HUMERUS.

A, Shaft appears at eighth week of intra-uterine life; B, centre for head in first year; C, centre for great tuberosity in third year; D, centre for lesser tuberosity in fifth year. B, C, and D fuse in sixth year to form one epiphysis, which joins the shaft at twentieth year.

E, Centre for capitellum in third year; F, centre for trochlear surface in eleventh year; G, centre for internal condyle in fifth year; H, centre for external condyle in twelfth year. E, F, and H coalesce about the fourteenth year and join the shaft at the seventeenth year; G remains separate until the nineteenth year.

3. Fracture of the **Condyles** (Fig. 295) usually results from direct injury, though the outer is sometimes broken by indirect violence, such as a fall on the hand, since the laxity of the elbow-joint on this side allows considerable mobility between the radial head and the capitellum of the humerus. Fracture of the **external condyle** (Fig. 295, A) always involves the elbow-joint, and is more common than that

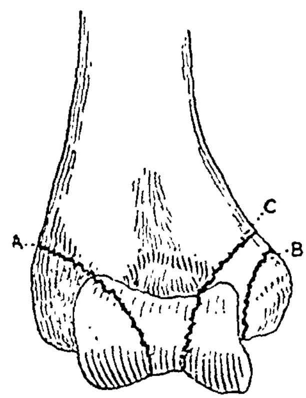


FIG. 295.—FRACTURES OF CONDYLES OF HUMERUS.

A, of external condyle.
B, of internal epicondyle.
C, of internal condyle.

of the inner. The line of fracture runs from the condyloid ridge downwards and inwards so as to separate the capitellum, or even to encroach upon the trochlear surface. The fragment is rotated forwards, and can be felt to move independently with crepitus, which may also be produced by rotation of the hand and radius. The acci-

dent is associated with much pain and ecchymosis. Fracture of the **internal condyle** may be intra- or extra-capsular. The *extra-articular* variety (Fig. 295, B) consists of a mere displacement of the tip of the condyle (or epicondyle), and in young people is probably a separation of the epiphysis, which remains distinct from the shaft till the age of eighteen or nineteen years (Fig. 294, G). The small fragment is drawn a little downwards by the muscles attached to it, and may be associated with injury of the ulnar nerve. The *intra-articular* form (Fig. 295, C) is the more common, and extends from the condyloid ridge to the trochlear surface, implicating the coronoid and olecranon fossæ. The fragment is displaced a little upwards and backwards, the ulna usually accompanying it, so that on extending the elbow the olecranon appears unduly prominent, the lower end of the humerus projects anteriorly, and the forearm is slightly adducted (cubitus varus). The ulnar nerve may also be injured in this case.

Treatment.—Complete flexion of the elbow with traction downwards of the forearm in the direction of the axis of the limb will often enable the surgeon to manipulate the fragment into position. If the arm is then fixed in front of the chest with the elbow fully flexed, and the hand pronated and resting under the chin, repair in good position may be obtained. Movements follow along the lines indicated on p. 585; too vigorous massage and passive movements are harmful rather than beneficial.

A failure to secure complete reposition of the fragment will necessitate open operation, and its fixation by wire, bone-peg, or screw; but as already noted, this is undesirable in children.

4. **Fractures in the Neighbourhood of the Lower Epiphysis of the Humerus** and involving its complete or partial separation are very common accidents in children. At birth and for some years afterwards the epiphysis consists of a single mass of cartilage (Fig. 294), including the two condyles as well as the articular surface, and these are all involved in any separation, together possibly with a fragment of the diaphysis.

As, however, growth and ossification proceed, the shaft encroaches rapidly upon the inner portion of the epiphysis, so that the epiphyseal line becomes almost rectangular, the internal condyle being isolated from the rest of the epiphysis. As a result, this type of injury after the age of six or seven is placed at a somewhat higher level, and scarcely ever encroaches on the epiphyseal line. It is usually transverse and runs through the olecranon fossa. The displacement is generally backwards, often with some amount of lateral displacement or deviation. **Treatment.**—Reduction can usually be accomplished by flexion with some amount of traction. In young children, as in adults, it is best to avoid splints, and trust merely to keeping the limb in a state of full flexion, the hand being in pronation. Where there is much swelling from hæmorrhage, it may not be possible to gain complete flexion at once, but as the swelling subsides it can be gradually increased. In a few cases it may be desirable to make an incision through the periosteum on one or both sides of the bone, so as to allow the blood to escape and enable the lower fragment to be

manipulated into position; but no attempt should be made to fix it by nails, screws, or wire. Flexion is maintained with the hand just below the chin for two or three weeks, or until all local tenderness has disappeared, and then the sling is relaxed so as to allow the hand to drop 3 inches, and the after-course is as for the transverse supra-condyloid fractures. Parents must, however, always be warned from the first that a perfect restoration of function cannot be guaranteed, as the fossæ at the lower end of the humerus are encroached on and are liable to be filled up with bone, and hence complete flexion or extension may be hindered. Some amount of deformity also may persist, and growth subsequently may be defective or irregular, giving rise to cubitus varus or valgus.

Fractures of the Ulna.—1. The **Olecranon** is frequently broken by direct violence, the patient falling on the bent elbow, but occasionally by muscular action. The line of fracture usually runs through the base of the process at its attachment to the shaft, and is for the most part transverse. Should the tendinous and periosteal coverings of the bone remain intact, there is but little separation; but if the fracture is complete, the detached fragment is drawn up by the triceps and tilted backwards, whilst the bones of the forearm are subluxated forwards. Great swelling in and around the joint comes on early; on examination, the detached fragment can be readily distinguished, and between it and the shaft a sulcus, which increases on flexing and diminishes on extending the forearm. If the fragments are not brought accurately into apposition, fibrous union occurs, and although the new cicatricial tissue may stretch considerably, a useful elbow sometimes results; in some cases the fragment is drawn up and fixed to the humerus, and a false joint is developed below it. If, however, the fragments are brought in contact, bony union follows, though even then some impairment of function may result from the formation of adhesions. In all cases the ulnar nerve is exposed to injury, though it is rarely affected.

Treatment.—An endeavour may be made to approximate the fragments manually and to maintain this reduction by a well-moulded slab secured with some turns of plaster bandage with the arm set at a right angle.

If this fails or if the bony fragments are obviously too far separated, it is better to cut down on the affected region, and, after cleaning out blood-clot and shreds of tendon, the fractured surfaces are brought together with lion forceps. They are maintained in position by suture of the aponeurosis over the olecranon, or preferably by drilling two transverse holes, one through each portion of the bone, threading a piece of silver wire, kangaroo tendon, or even ordinary catgut through these holes and tying, thus approximating the broken surfaces.

The limb is then put up in plaster in a position of mid-pronation with the elbow bent to a right angle for three weeks.

2. The **Coronoid Process** is so deeply placed and so well protected that fractures must necessarily be very uncommon, except as an accompaniment of dislocation of the ulna backwards. The signs relied on in making a diagnosis are that reduction of the dislocation is easier

than usual and associated with crepitus, and that the deformity is likely to recur. The **Treatment** consists in apposing the bony surfaces, if possible, by complete flexion of the forearm.

3. The **Shaft of the Ulna** is often fractured by itself as a result of direct violence, to which its exposed position renders it peculiarly liable. Fracture also occurs as a complication of several of the forms of dislocation of the radius alone. The superficial position of the posterior border renders examination of the bone easy; if displacement or a breach of substance occurs, it is readily detected, but when merely a fissure exists, it is not so easy to make out. The constant pain referred to one spot, the slight mobility, and possibly crepitus, indicate the character of the lesion. No longitudinal displacement can occur if the radius remains intact, and under such circumstances the only deformity consists in a slight drawing forwards of the upper fragment by the brachialis anticus, whilst the lower fragment is approximated to the radius by the pronator quadratus. **Treatment.**—The arm is placed midway between pronation and supination, the deformity corrected, and the limb kept at rest between anterior and posterior splints, or in plaster of Paris.

4. The **Styloid Process** may be detached by direct violence, or as a complication of fracture of the lower end of the radius. The displacement may be considerable and very evident, being governed by the direction of the violence. **Treatment** consists in replacing the fragment by manipulation, and applying a plaster cast extending from the knuckles to the elbow for three weeks.

Fractures of the Radius.—1. The **Head of the Radius** may be broken alone, but this accident is often associated with other injuries to the elbow, as, for instance, fracture of the outer condyle or some form of dislocation. The line of fracture may be transverse or vertical, or comminution may occur; the displacement is slight if the orbicular ligament remains intact. In complete separation the head is immovable, and crepitus is produced when the arm is rotated; bony union usually follows, with more or less impairment of function, but sometimes the head, or a portion of it, remains detached as a loose body; in the latter case the small fragment may get between the articular ends from time to time and lock the joint. **Treatment.**—If there is little displacement, or if manipulation results in a good reposition of the fragments, the arm is placed in a plaster cast extending from the knuckles to half-way up the humerus with the forearm in a position of supination for four weeks.

2. The **Neck,** *i.e.* the portion between the orbicular ligament and the biceps tuberosity, is occasionally broken. The lower fragment is drawn upwards and forwards by the biceps, causing a bony projection on the front of the elbow, especially evident on attempting to flex the joint, whilst the forearm is pronated with loss of the power of rotation, and the head of the bone does not accompany the shaft on rotating it passively. **Treatment.**—This is similar to the treatment outlined for fractures of the head.

3. The **Shaft** of the radius is not unfrequently broken by direct violence or more rarely by falls on the palm; the latter accident,

however, rarely causes fracture except at the lower end. Many types of *chauffeur's fracture* of this bone have been described, but most often it involves the lower end of the radius, about 2 to 3 inches above the wrist, and results from a jerk backwards, of the starting handle of the car due to premature ignition. Well-marked anterior displacement is usually present.

There is usually little difficulty in diagnosing a fractured radius; the chief signs are localized pain and loss of power of active rotation, whilst passive rotary movements are accompanied by crepitus, the head of the bone and upper fragment remaining immobile below the outer condyle, unless impaction is present. The *displacement* is somewhat characteristic. If the fracture is situated *above the insertion of the pronator teres*, the upper fragment is flexed and fully supinated by the action of the biceps and supinator brevis, whilst the lower fragment is drawn towards the ulna and fully pronated by the unopposed action of the two pronator muscles.

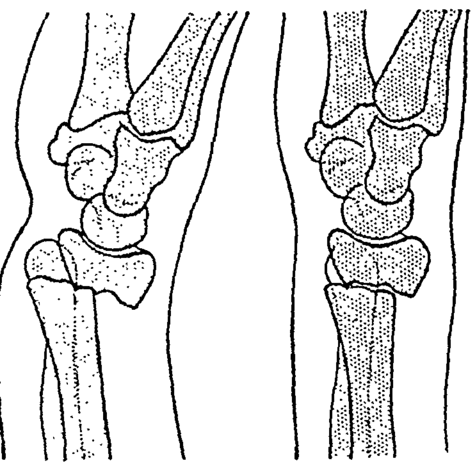
When the fracture is placed *below the insertion of the pronator teres*, the upper fragment is drawn forwards by the action of the biceps, and inwards by the pronator, assuming a position midway between pronation and supination; the lower fragment may be slightly approximated to the ulna by the direct action of the pronator quadratus; the hand is fully pronated looking downwards. Union to the ulna by callus thrown across the interosseous space has been known to occur.

Treatment.—In those fractures situated above the insertion of the pronator radii teres muscle, the limb must be reduced and set up after reduction in a position of full supination. If this is not carried out, perfect apposition of the bony ends cannot be obtained. If the arm is pronated, the pronators of the lower fragment relative to that of the upper is much greater, the tendons of abductor pollicis longus and the extensor pollicis brevis are drawn taut and tend to squeeze the lower fragment towards the mid-line.

In fractures situated below the insertion of this muscle, however, the limb should be put up in a mid-position. Reduction can usually be effected by traction exerted on the forearm by an assistant pulling on the fingers and the thumb, while counter-traction is maintained either by a second assistant grasping the upper arm or by passing it through a fixed webbed band, the surgeon manipulating the bony ends into position. A plaster slab is then applied to the extensor surface of the limb extending from the knuckles to half-way up the arm; this is maintained in position by several turns of plaster bandage. The plaster is kept on for a period of five to six weeks. Occasionally, in spite of easy reduction, owing to the tearing of the ligaments of the inferior radio-ulnar joint, as soon as the traction has been removed the displacement recurs. In these cases one of two procedures may be employed. An open operation may be advised with fixation of the fragments by a bone peg or a Lane's plate; or Böhler's method may be employed. This consists in passing a wire or pin, one through the olecranon process and another through the lower end of the radius and ulna. The fracture is then reduced in the usual way and the

plaster applied to incorporate the projections of the wires. When the plaster has set and the traction is released the fragments cannot slip, as they are maintained in position by the wires, the ends of which are embedded in the plaster.

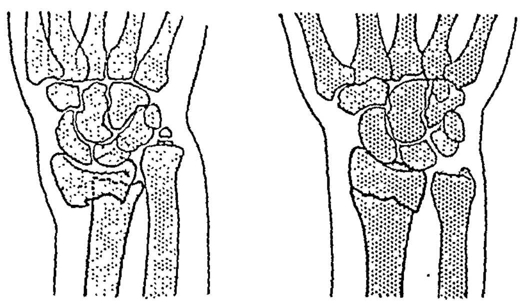
4. The **Lower End of the Radius** is broken with extreme frequency, constituting what is known as **Colles's Fracture.** This injury occurs most commonly in women of advanced years, although it may happen at any age or to either sex. It is almost invariably due to falls upon the outstretched palm, when the hand is completely pronated and extended. The line of fracture is placed about 1 inch from the wrist, though rather under than over this. It is usually transverse from side to side, but is oblique in an antero-posterior direction, sloping from above downwards and forwards, so that the fracture is nearer the wrist-joint in front than it is behind (Figs. 296 and 297).



(a) (b)

FIG. 296.—TRACINGS FROM X-RAYS OF A COLLES'S FRACTURE.

(a) Backward tilt of lower fragment; (b) tilt corrected, but slight backward displacement still remains, a result compatible with reasonable function.

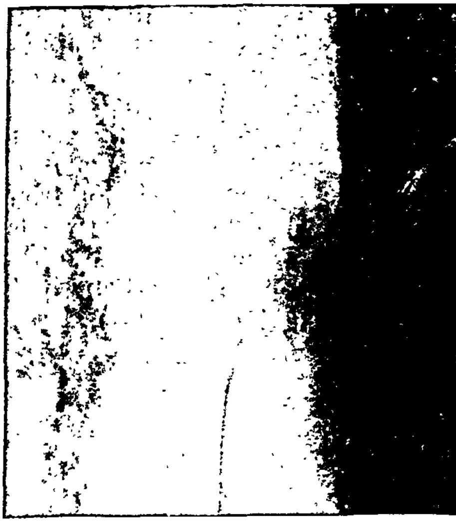


(a) (b)

FIG. 297.—COLLES'S FRACTURE, SHOWING (a) RADIAL DEVIATION AND IMPACTION, (b) AFTER REDUCTION.

The *displacement* is somewhat complicated. (a) The lower fragment is carried backwards and a little upwards, owing to the direction of the violence, *viz.* a fall on the outstretched hand, the radius being compressed between the ground and the weight of the body, and yielding at what is evidently a weak spot; this deformity is maintained by the radial extensor muscles of the wrist, and often by impaction of the fragments. (b) From the fact that the main violence is received on the thenar eminence, the outer side of the lower fragment is displaced more than the inner, which remains fixed to the ulna by the strong inferior radio-ulnar ligaments. This position is in part kept up by the extensor of the thumb and the supinator longus, but mainly by impaction of the fragments (Figs. 298 and 299). The hand and carpus always follow the lower fragments, and hence the former is abducted, causing the styloid process of the ulna to become unduly

prominent, and lower than that of the radius, whereas it is normally placed on a slightly higher level. In bad cases the styloid process of the ulna is actually torn off, or the internal lateral ligament ruptured, allowing displacement outwards of the whole hand. (*c*) The



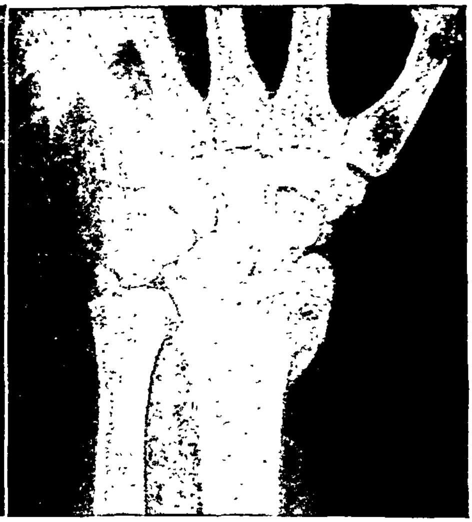


FIG. 298.—COLLES'S FRACTURE: LATERAL VIEW.

FIG. 299.—COLLES'S FRACTURE: POSTERO-ANTERIOR VIEW.

The lower radial fragment is impacted and displaced outwards and backwards.

lower fragment is also rotated around a transverse axis, so that the lower articular surface looks backwards as well as downwards, a displacement due to the fact that in falling the force is directed, through the carpus, more to the posterior than to the anterior aspect of the bone. (*d*) The upper fragment is pronated and approximated to the ulna by the pronator quadratus muscle. The *deformity* produced by the fracture is therefore very characteristic. The hand is in a position of radial abduction, and usually pronated, with the fingers somewhat flexed (dinner-fork deformity). Three abnormal osseous projections are present: (i.) The styloid process or head of the ulna is very marked, owing to the radial abduction of the hand (Fig. 301); (ii.) on the back of the wrist is a prominence which terminates abruptly above, caused by the projection of the lower fragment (Fig. 300); and (iii.) corresponding to this dorsal projection there is a well-marked depression on the palmar surface, and above it a less sharply defined swelling, which gradually shelves into the forearm, due to the upper fragment. Pronation and supination are lost, and, as a rule, there is neither

FIG. 300.—COLLES'S FRACTURE: LATERAL VIEW.

crepitus nor preternatural mobility, owing to impaction of the fragments. An important diagnostic point is the relative position of the two styloid processes; normally, that of the radius is below that of the ulna, but in cases of fracture it is on a level with or above it.

The fracture is commonly impacted, the upper fragment being *firmly driven into the cancellous tissue of the lower end;* excess of violence may, however, disimpact, but often at the expense of comminution of the lower fragment. Union is effected without difficulty, but the patient should always be warned at an early date that some deformity may persist about the wrist, as well as some impairment in the subsequent mobility of the fingers and hand, owing to adhesions in the joint or tendon sheaths.

Treatment.—Early correction of the deformity is essential in every case. Even in elderly subjects, correction should be undertaken. Anæsthesia by nitrous oxide is usually sufficient, but should the general condition of the patient make the use of inhalation anæsthesia inadvisable, local anæsthesia gives excellent results, and is preferred by many operators.

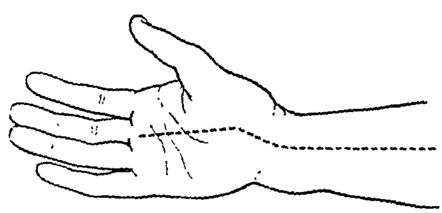


FIG. 301.—COLLES'S FRACTURE: PALMAR VIEW

The skin is cleansed and painted with iodine. A fine needle is inserted at the level of the fracture line and from the outer side. The piston is withdrawn and blood should flow into the syringe from the hæmatoma surrounding the fracture; 5 to 10 c.c. of 2 per cent. novocaine solution are then injected slowly. In the event of failure to withdraw blood, two or three separate injections must be made at different sites. After ten minutes, complete anæsthesia and muscular relaxation should be obtained.

Reduction is best effected by grasping the injured wrist between the two hands. One thenar eminence rests against the palmar aspect of the lower fragment, the other against the dorsal aspect of the radial shaft, just above the fracture. By firm pressure the deformity is increased by forcing the lower fragment backwards, thus disimpacting the fracture. A slight 'wriggle' will aid the manœuvre.

The position of the thenar eminence of the operator is now changed, that on the dorsal aspect making contact with the lower fragment, while that on the palmar side makes contact with the shaft. Firm pressure now causes reduction of the deformity, and at the same time the patient's hand is carried into *adduction.*

The manipulation may be summed up thus: increase deformity to disimpact, reduce, ulna deviate. 'A firm grip with slight traction and twist of the wrist completely reduces the deformity. It requires knack rather than strength' (R. Jones).

The completion of the reduction is recognized by the restoration of the normal concavity on the anterior surface of the lower end of the radius and by the relative positions of the two styloid processes. The position of the fragments should always be checked by X-ray photographs taken in two planes after the splint has been applied.

Splintage.—A splint should always be applied, even where the initial fracture has been merely a 'crack' with no deformity.

Care should be taken in applying the splint that the deformity does

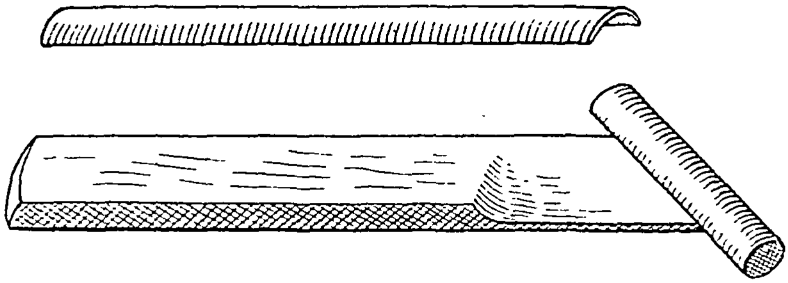


FIG. 302.—CARR'S SPLINT FOR COLLES'S FRACTURE OF LEFT HAND.

not recur, although in the majority of cases this will not happen with gentle handling.

(1) *Carr's Splint* (Fig. 302) may be used. Although supplied in two portions, it is only necessary to use the palmar half. To this is attached an oblique rod, which may be grasped by the fingers, so maintaining the hand in a position of ulnar deviation. The splint should be padded with thick felt and an extra pad placed at the wrist, so that this joint is maintained in slight palmar flexion. The splint is fixed in position by two bands of adhesive strapping, one situated in the upper part of the forearm, the other crossing the dorsal aspect of the hand.

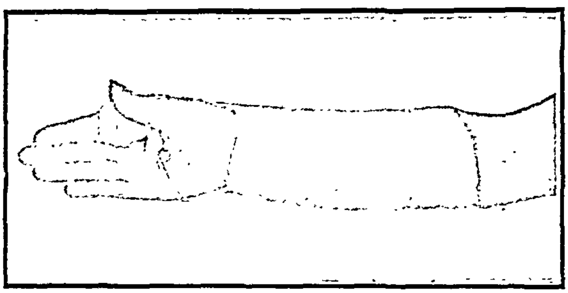


FIG. 303.—PLASTER APPLIED TO COLLES'S FRACTURE.

(2) By far the most effective method of fixation is plaster of Paris. A 'slab' is made from eight layers of bandage and of a length to extend from below the elbow to the knuckles. It is applied to the dorsal aspect of the forearm and hand, either direct to the skin or over a single layer of flannel, and bandaged into position with flannel bandage. It must *not* be wide enough to encircle the limb completely. A thin 'twist' of plaster or a piece of stout wire is carried, between

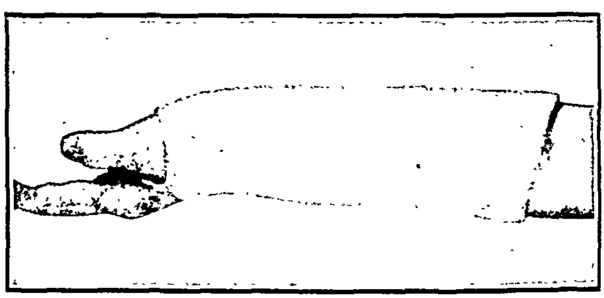


FIG. 304.—PLASTER FOR COLLES'S FRACTURE.

the thumb and first finger, across the palm. The hand is held in *slight* palmar flexion and ulnar deviation until the plaster has 'set' (Figs. 303 and 304).

After-Treatment.—Active movements of the fingers, thumb, elbow and shoulder must be encouraged from the outset. Union is seldom firm under *three weeks*, and should tenderness persist the splint should be retained for four or five weeks. The use of a sling should be discouraged. In younger people, no massage is necessary until the splint is removed, but in older patients it may be advisable to start gentle massage at the end of four or five days, in which case a Carr's splint, rather than plaster, should be employed.

A fracture of the lower end of the radius, known as *Smith's fracture*, is occasionally met with, in which the displacement of the fragment is exactly the reverse to that seen in Colles's fracture, *viz.* the lower end of the radial shaft projects posteriorly, whilst the lower fragment is displaced anteriorly. **Treatment** is conducted as for a Colles's fracture.

5. **Separation of the Lower Epiphysis** of the radius occurs in young people under twenty, and when it is displaced backwards simulates somewhat closely a Colles's fracture (see Fig. 267). The lower end of the diaphysis projects anteriorly to a much greater extent, and, indeed, may protrude through the skin of the wrist, and then grave septic complications may supervene, leading to more or less extensive necrosis; indeed, the author has removed the whole shaft of the radius as a sequestrum due to acute osteomyelitis caused in this way. The lower end of the ulna may be involved in the accident, either the epiphysis being separated or the shaft broken a little above. This condition may be mistaken for a backward dislocation of the wrist, but a diagnosis can be readily made by observing the relative position of the styloid processes to the carpal bones. Lateral displacement occurs in some cases. **Treatment** is practically the same as for Colles's fracture.

Should arrest of growth result, the hand retains its connection with the stunted radius, but the ulna continues to grow downwards, and its lower end projects on the inner and posterior aspect of the carpus, which is pushed *en bloc* towards the radial side, but without any marked abduction (Madelung's deformity).

Fracture of both Bones of the Forearm may result from direct violence or falls on the palm. Any part of the bones may yield, but the middle and lower thirds are most frequently affected. When due to direct violence, both bones may be broken at the same level; but if due to a fall on the palm, the ulna usually gives way at a higher level than the radius. The line of fracture may be transverse or oblique, and the displacement varies both with this and with the force employed. The upper fragments are usually drawn together and pronated, whilst the lower end of the radius is drawn up by the supinator longus. In young people a not uncommon result of falls in the football field or at the skating-rink is a complete fracture of the lower third of the radius, and a green-stick fracture of the ulna (Fig. 266). The upper fragment of the radius is displaced forwards in front of

the pronator quadratus, which prevents its replacement even by traction under an anæsthetic. The diagnosis is usually simple, since there is, as a rule, obvious deformity.

Treatment.—It is most important in this fracture to restore the bones completely to their correct alinement, since failure to do so almost always involves serious impairment of function, both as regards rotation and the movements of the fingers. In a few cases cross-union follows, but this is not common when reasonable precautions have been taken. Under general or local anæsthesia traction is exerted in the manner described above, the forearm being either supinated or pronated according to the position of the radius in relation to the pronated radii teres. The surgeon manipulates the fractured ends into alinement and then applies a plaster slab extending from the knuckles to well up the arm proximal to the elbow; this is then covered by a plaster bandage, the whole being carefully moulded to support the bones at the site of the fractures. The plaster should remain on for at least six weeks. If on relaxing extension there is a recurrence of the displacement, one of two procedures may be adopted. Böhler's manœuvre, in which a wire is passed through the lower ends of the radius and ulna and another through the olecranon, and after reduction in the way previously described the ends of the wires are incorporated in a plaster case and so preventing any alteration in the position of the bones, is most valuable. Alternatively open operation and fixation of the fragments may be advised.

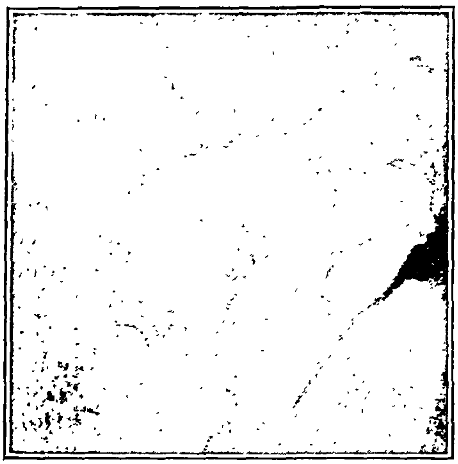


Fig. 305.—Fracture of the Scaphoid some Six Weeks after a Sprain of the Wrist.

The fracture was not diagnosed until after an X-ray had been taken.

The ulna is easily exposed by an incision along its posterior border; but it is less easy to reach the radius without damaging the muscles. The incision should pass behind the supinator longus, between it and the radial extensor tendons; the origin of the extensor muscles of the thumb may have to be disturbed, but with care no permanent damage follows; in the upper part the position of the posterior interosseous nerve must be remembered. The ends of the bones are freed and brought into position, and fixed by suitable means; a plate to the radius is sometimes needed, but the ulna may usually do without it.

Fractures of the Carpus.—These may result from direct violence in the nature of a severe crush, and then several of the bones may be involved, and the lesion may be compound. The ordinary treatment of such a condition must be followed, and the part kept at rest on a palmar splint.

Any injury to the wrist of more than minimal severity should be X-rayed to exclude the possibility of injury to the scaphoid bone. In the past many injuries have been treated as sprains which in point of fact were undoubtedly fractures of the scaphoid; and inefficient treatment spells a lifetime of pain and limitation of the use of the wrist. The blood-supply of the scaphoid bone is by means of two vessels, one entering the tuberosity and the other the middle of the bone. If a fracture occurs through the proximal part or through the centre in such a way as to damage the artery in that position this will result, with inefficient immobilization, in the death of that portion as a consequence of its insufficient blood-supply. This is associated with pain on dorsiflexing the wrist, subsequent arthritis

FIG. 306.—FRACTURED METACARPAL BONES.

and general rarefaction of the carpal bones. The patient complains of pain in the region of the anatomical snuff-box associated with some swelling and pain on dorsiflexion. X-ray may reveal a crack in the scaphoid at first only recognizable with a lens, but if the joint is not immobilized this crack will become very obvious in the course of a few weeks (Fig. 305). **Treatment** for this condition consists in complete immobilization of the wrist by a plaster extending from the knuckles to high up in the forearm, immobilization being maintained until union of the fragments is completed, a process which will take some twelve weeks or more.

Fractures of the Metacarpal Bones and Phalanges (Figs. 306 and 307) are not uncommon, particularly in the third and fourth fingers, being

due to direct violence, and hence often transverse. There is generally but little displacement, though occasionally the fragments may overlap, whilst a certain amount of localized swelling and tenderness is always noted.

Treatment of a fractured metacarpal with little or no displacement is merely immobilization of the hand of a cock-up splint for two weeks or so; but if the fragments overlap and shortening of the finger is threatened, prolonged extension is required. This is easily

FIG. 307.—FRACTURE OF FIFTH METACARPAL BONE AT ITS NECK.

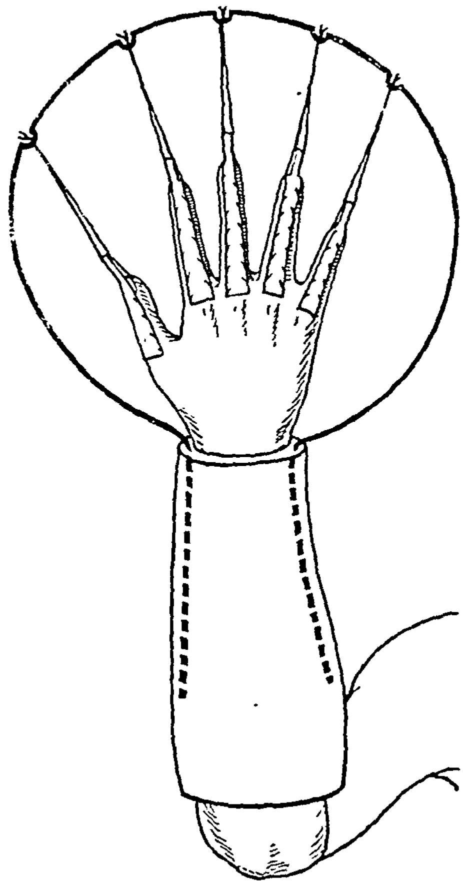


FIG. 308.—TREATMENT OF FRACTURED FOREARM OR METACARPALS BY EXTENSION.

This appliance could also be utilized for some less serious cases of fracture of the forearm needing extension where the patient cannot remain in bed. The lateral bars must then be carried up either side of the arm and join together behind the elbow, which is fixed to them so as to give support for counter-extension.

effected where one metacarpal alone is involved by applying a metal palmar plate, to which is fixed a solid bar reaching below and beyond the finger. Adhesive plaster is fixed to the finger front and back by encircling strips, or the finger of a glove is glued on, and tape carried through the tip. These bands tied firmly to the rounded termination of the projecting bar provide the needful extending force. If several metacarpals are broken, it is better to apply a light plaster case to the forearm, in which is incorporated a piece of heavy-gauge wire, bent as in the illustration (Fig. 308). The extension tapes

from the fingers are tied to the wire loop in the manner shown. Operation for these conditions is undesirable, as it almost certainly interferes with the tendons, and their subsequent mobility is jeopardized.

Bennett, of Dublin, has described an interesting fracture of the first metacarpal (*stave of the thumb*), which is due to indirect violence, and not very rare. The line of fracture is oblique (Fig. 309), separating the anterior portion of the base, which remains *in situ*, from the rest of the shaft, which is drawn upwards and backwards by the long extensor tendons, so as to lie behind the trapezium. Should the displacement be overlooked, the bone unites in this position, and the deformity, which persists, determines weakness and disability of the thumb.

Treatment.—Reduction is usually effected with ease by traction, and prolonged extension as described above is necessary.

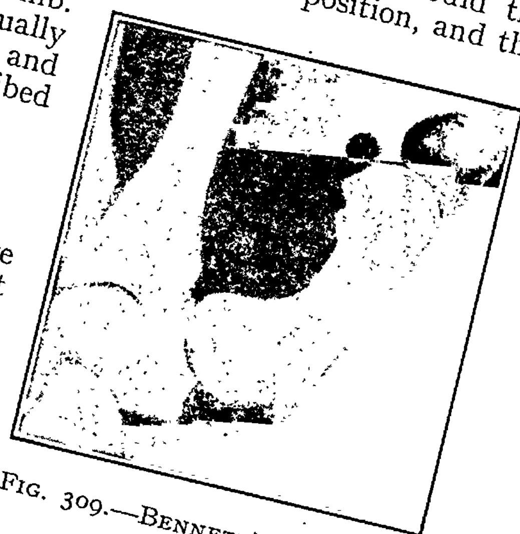


FIG. 309.—BENNETT'S FRACTURE.

Fractures of the Pelvis.

Fractures of the pelvic bones are almost always the result of direct injury, such as falls, blows, gunshot wounds, or crushes in railway, carriage, or motor accidents. For convenience they may be described under the following headings:

1. **Fractures of the False Pelvis.**—A portion of the crista ilii may be broken off, or the anterior superior spine separated, or merely a fissure in the bone produced. The displacement is rarely great, although a portion of the crest may be drawn down by the glutei muscles, or the anterior superior spine displaced by the sartorius. Considerable pain is always present, especially on any vigorous respiratory movements, but crepitus is rarely to be detected. Union occurs readily if the patient is kept quiet in bed with the shoulders raised, and the legs supported to relax the muscles. A flannel bandage round the pelvis gives comfort and support.

Septic penetrating wounds, such as follow gunshot injuries, are liable to result in a subacute spreading osteomyelitis which is most troublesome. Not unfrequently an abscess forms on the inner aspect of the bone, communicating with the exterior by the narrow passage in the bone made by the penetrating body. Pus may track up and down the iliacus muscle, and the cavity fills and empties itself through the wound from time to time. The only treatment that is effective consists in opening up the external wound and enlarging the aperture in the bone so as to secure effective drainage; or it may be necessary to open up the iliac fossa from the front, burrowing through and under the iliacus muscle.

2. **Fracture of the True Pelvis** is a much more serious accident.

The line of fracture in front usually runs into the obturator foramen, and involves both the horizontal and descending rami of the pubes or the ascending ramus of the ischium (Fig. 310). This is frequently conjoined behind with a fracture in the neighbourhood of the sacro-iliac synchondrosis either on the same or opposite side, but more frequently the latter. The **Symptoms** are those of severe shock and pain in and around the pelvis, especially on movements of the legs or on coughing. There may be local ecchymosis and tenderness over the pubic ramus, as also deeply in the iliac fossa, and the patient either cannot stand, or feels as if he were falling to pieces on attempting to do so. Usually there is but little deformity, although occasionally displacement backwards of the innominate bone is visible, and depression of the pubic symphysis or of the ischial or pubic rami may be palpable. Crepitus may be elicited on grasping the iliac bones, and moving them one on the other; but such a method of investigation must be indulged in very sparingly.

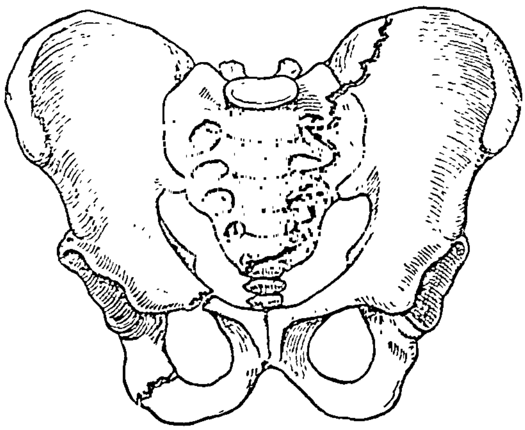


FIG. 310.—FRACTURE OF THE PELVIS.

The fracture runs through the sacrum on the left side, and through the horizontal and descending rami of the pubes of the opposite side.

The chief dangers from a fractured pelvis arise from the presence of co-existent *visceral lesions*, especially to the urethra, bladder, or rectum. The membranous portion of the urethra is torn by the displacement of the pubic symphysis, and this is indicated by escape of blood from the meatus. Every effort must be made to prevent extravasation of urine, and *the patient warned against passing water, however urgent the desire.* Rupture of the bladder results in pelvic or intraperitoneal extravasation, according to the site of the lesion. The rectum may be punctured by the displaced pubic rami, and on examination the ends of the bones may be felt in the rectum. The vagina and the pelvic vessels and nerves are less frequently injured.

Treatment.—The patient should be moved with the greatest care, both on account of the shock and also for fear of producing or increasing visceral complications. As a first-aid measure a binder may be fixed round the pelvis. He is put to bed on a divided mattress (Fig. 327) with fracture-boards beneath it, and kept quiet until the shock has in measure passed off. The treatment of the actual fracture will depend on whether a single or a double break in the continuity of the pelvic ring exists. If there is a break through one or both of the pubic rami, through the body of the ilium, or if there is a break in the symphysis pubis, it is quite obvious that no deformity can occur, and treatment of these cases by rest in bed for three weeks is all that is required.

Where a double break is present there is likely to be some displacement, usually more marked towards the front of the pelvis than at the back, as in these fractures the pelvis tends to open like a book, the binding being placed posteriorly. In some cases the displaced fragment is also pulled upwards. If the patient is compressed while standing sideways, the anterior segment will break through both pubic rami or through the pubic ramus of one side and the symphysis pubis. There is some upward displacement of the separated part, the replacement of which can sometimes be effected by manipulation. Some displacement, however, is of little moment, and these patients treated by rest in bed in a supine position for from four to six weeks do very well.

Where there is a fracture through the symphysis or pubic bones associated with one through the sacro-iliac joint or the body of the ilium, that half of the pelvis will be displaced upwards. Reduction can be effected by supporting the patient on a plaster table on the sound side and exerting traction on the leg of the fractured side. A double plaster spica is then applied. This remains on for a period of three months, during which time the patient is encouraged to lie on the sound side.

A very careful examination is made to exclude visceral injuries.

1. *Ruptured Urethra.*—Bleeding from the meatus and bruising and swelling often of a butterfly shape in the perineum suggest this lesion. Under full aseptic technique an endeavour is made to pass a catheter. If failure results the urethra is probably completely torn; whereas if the catheter is passed successfully a partial tear is likely to be present. In the latter case it is probably best to leave a catheter in for some fourteen days, and from then on to subject the patient to periodic bougie treatment to avoid the formation of a stricture. If suppuration occurs in the perineum this must be incised and the bladder drained suprapubicly. Some surgeons advise incising over the perineum and passing a catheter from the incision into the bladder, the wounded urethra being repaired subsequently when all the œdema and bruising has subsided. Where there is a complete rupture of the urethra a suprapubic cystostomy should be performed at once, the repair of the urethra being effected at a later stage.

In those injuries in which the membranous urethra is torn great difficulty is experienced in approximating the ruptured ends, as the prostate and bladder tend to fall upwards and backwards and at the same time there is little tissue in or around the distal ruptured end through which a suture may be introduced. There is in these cases complete inability to pass a catheter, and on suprapubic cystostomy the location of the rupture will be evident. The following procedure is then adopted. A retrograde catheter fitted with a flange at the end opposite to the eye is passed through the prostatic urethra and its end drawn up into the suprapubic wound. A second catheter is then passed down the penis and as it emerges through the ruptured membranous urethra is also drawn up into the suprapubic wound. The ends of the two catheters are united with a thread, and the retro-

Fractures of the Upper End of the Femur.

1. **Transcervical or so-called Intracapsular Fracture** (Fig. 311).—This is most frequently met with in persons of advanced age, and especially in females. This is explained by the atrophic changes which take place in the cervix femoris of elderly people. The spaces between the bony cancelli are enlarged and loaded with soft fat, whilst the ensheathing compact tissue is thinned and the 'calcar femorale' of Merkel, *i.e.* the process of thick cortical substance running from the lesser trochanter to the under part of the head, is atrophied. It often requires but little violence to produce this fracture, the causative accident being merely some slight stumble or fall, such as slipping off the kerb or tripping upstairs; the bone yields, and the patient falls to the ground. The line of fracture varies, being either transverse or oblique, and is mainly intracapsular. Some of the fibres reflected from the under surface of the capsule to the neck of the bone may remain untorn at first, but later on they may give way from reactionary softening, injudicious manipulation, or attempts to use the limb. Two types of this fracture must be differentiated from the point of view of diagnosis, prognosis, and treatment: the abduction fractures, which are rare, and the adduction fractures, which are common (80 per cent.).

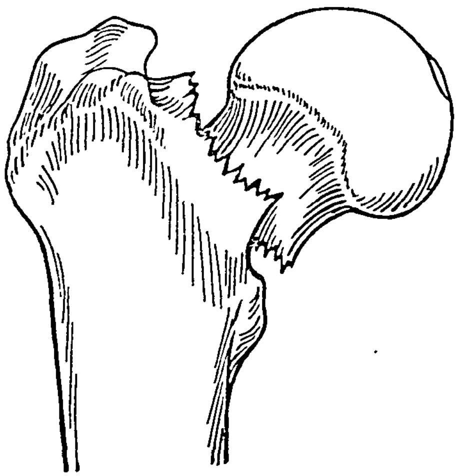


FIG. 311.—TRANSCERVICAL (INTRACAPSULAR) FRACTURE OF THE CERVIX FEMORIS.

The history given in both cases of some trivial injury is similar, and there may be a certain amount of shock associated with the pain of the fracture. On examination, in the majority of cases, the limb is rolled out in a position of eversion, this being largely due to the action of gravity. Some adduction is also present. Shortening of the leg by half an inch or so can be demonstrated by a measurement taken from the anterior superior iliac spine to the internal malleolus; and in addition the great trochanter will be found to be raised. This is best demonstrated by the following tests.

Nélaton's Line (Fig. 312) is one drawn from the anterior superior spine to the most prominent point of the tuber ischii (AB). The centre of this (D) corresponds to the top of the great trochanter, if the limb is placed in the axis of the body, but if either abduction or adduction is present the top is situated slightly above or below the line. Definite elevation of the bone above the line indicates shortening of the limb due to dislocation backwards, fracture of the neck, or absorption of the head and neck from disease.

Bryant's Test Line (Fig. 312). In this the patient lies flat on a horizontal couch, and a vertical line (AC) is drawn from the anterior

superior spine; a thin wooden rod held against the side answers this purpose admirably. The perpendicular distance of the top of the great trochanter from the line (CD) is compared with a similar measurement of the opposite side; definite shortening may thus be discovered. In the normal adult this measurement is usually about $2\frac{1}{2}$ inches.

In the abduction fracture there is no external rotation, and some degree of internal displacement may be present. It will be found that as opposed to a degree of coxa vara present in the adduction type, there is in this fracture some coxa valga, with lowering of the great trochanter as determined by the tests described above. X-ray examination will often show impaction of the fracture with the fragments rotated in such a way that an angle opening forwards and outwards, as opposed to the disimpaction and the angle opening backwards and inwards in the adduction variety.

Treatment.—That of the abduction type of fracture is simple, as union readily occurs. All that is necessary is to place the affected thigh in a plaster spica extending down to the knee on the injured side. This is kept on for some three months, weight - bearing being allowed from the commencement.

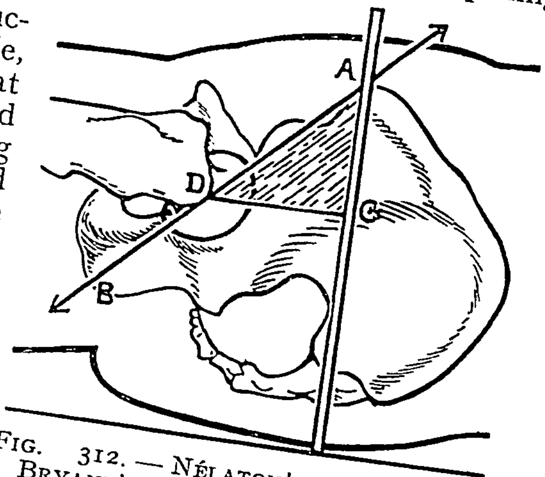


FIG. 312. — NÉLATON'S LINE AND BRYANT'S MEASUREMENT FOR ASCERTAINING POSITION OF GREAT TROCHANTER.

With the adduction fractures treatment is difficult and less satisfactory. Some years ago it was the custom to regard these fractures as ununitable, and the unfortunate patient was treated by rest in bed with half-hearted attempts at immobilization of the hip-joint with sand-bags. At the end of two or three months the patient was allowed up, with probably at the most fibrous union or a pseudo-arthrosis, often with a backward displacement of the femoral neck. Such treatment is occasionally practised to-day, but cannot be condemned too strongly except in exceptional cases, because they are deprived of the chance of obtaining bony union and full function. Two methods of treatment may be used, but in either a preliminary period of extension by means of skeletal or skin traction with the leg on a Braun's or Thomas's splint should be employed, as pain and shock are relieved thereby and the displacement is partially reduced.

(1) By means of a *Whitman's Plaster*. This is suitable for patients without chest complications such as bronchitis, and for those who apart from the fracture are comparatively fit. After spinal anæsthesia has been administered the patient is put on an orthopædic table and the sound leg fixed in abduction. Traction is then exerted on the injured limb by an assistant in an abducted position, and the knee

is then flexed so as to use the lower leg as a lever to obtain full internal rotation. The knee is straightened and pressure on the foot is exerted gently to impact the fragments. After padding all bony prominences with felt a well-moulded plaster is applied from under each axilla and including the whole of the affected limb. After about a week a walking iron projecting vertically down from the inner aspect of the affected leg is applied and the patient is encouraged to get about. The plaster is kept on for some six months, when bony union should have occurred. In some cases periodical X-ray examination will show that the head of the femur has become dense and necrotic, indicating that viability cannot be hoped for, and then the plaster must be removed.

(2) By means of a *Smith-Petersen Pin*. This is a triflanged stainless steel pin which, following the reduction of the fracture in the manner indicated above, is introduced into the neck of the femur through the great trochanter and thence on into the head (Figs. 313 to 315). Head and neck of the femur are then held immovably together, the three flanges on the pin preventing any rotation.

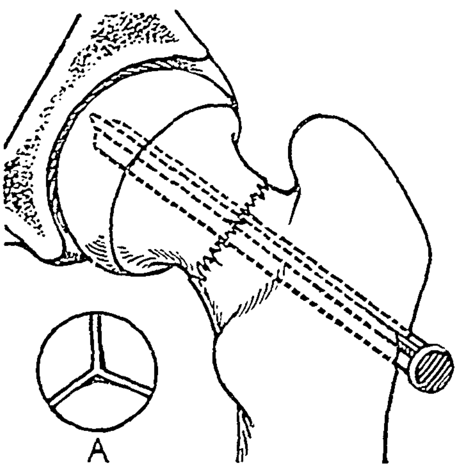


FIG. 313.—METHOD OF INSERTING SMITH-PETERSEN'S PIN FOR FRACTURE OF NECK OF FEMUR.

A, Cross-section of pin.

The pin is difficult to introduce, and one of two ways may be attempted, the open or the closed. In the former the hip-joint is exposed by an incision passing down from the anterior superior iliac spine on the outer aspect of the thigh. The rectus femoris muscle is retracted from the tensor fascia femoris and the upper part of the femoral shaft, the capsule, neck, and great trochanter are exposed. The capsule is incised and the fracture reduced. A pin, the length of which has been previously estimated, is then driven through the great trochanter. Rotation of the leg outwards will determine whether it is appearing at the mid-point of the fractured neck. If so, internal rotation of the leg is repeated and the pin driven home. If not, the pin must be extracted and the process repeated. A firm dressing is applied, and at the end of about a month the patient is allowed up, with a short spica plaster bandage which is retained for six months.

In the closed method two or three Michel's clips are applied to the skin in what is thought to be the projected line of the neck of the femur. An X-ray is then taken and all except the clips approximating to the mid-cervical line are removed. After exposure of the great trochanter two or three Steinmann's pins are driven in in the direction approximating to the line previously determined. Another X-ray is taken

and a Smith-Petersen pin driven along the best-placed Steinmann pin, and for this purpose the former is provided with a central longitudinally running channel. The guiding pin is removed and the wound closed. Subsequent treatment is similar to that previously described.

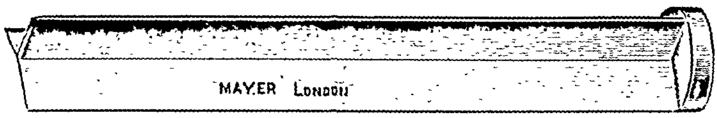


FIG. 314.—SMITH-PETERSEN'S PIN.

Non-union. In otherwise fit cases it is often worth while attempting some operative procedure to minimize the deformity. If the head is still viable, fixation with a Smith-Petersen pin is worth a trial; in other cases a subtrochanteric osteotomy in which the upper fragment is strongly adducted by a pin driven into it so that when union occurs some of the weight will be taken by the lesser trochanter. Whitman's operation, in which after removal of the head of the femur an attempt is made to fashion a new one from the neck of the femur, is worth a trial, the great trochanter being transplanted lower down the femoral shaft to permit of sufficient leverage for the glutei muscles.

FIG. 315.—SKIAGRAM SHOWING SMITH-PETERSEN'S PIN IN POSITION IN A CASE OF FRACTURE OF THE NECK OF THE FEMUR.

(3) Certain cases, unsuitable for treatment by the above methods, should be treated in bed, weight extension being applied by means of a Thomas's splint. After six to eight weeks walking is started with the aid of a caliper.

Massage and gentle movements can be initiated after three weeks, and particular attention should be paid to the knee-joint.

(4) Finally, in those patients too infirm for serious treatment to be attempted, hope of bony union must be abandoned and a caliper fitted at once. It should be stated, however, that good results following the use of the Smith-Petersen nail have been reported in patients over eighty years of age.

2. **Intertrochanteric Fracture of the Femur** (the so-called *extra-capsular fracture* of the neck), always involves the hip-joint, since the capsule extends to the shaft of the bone along the anterior inter-trochanteric line, and leaves no portion of the neck uncovered in this situation. The line of fracture is therefore only extra-capsular behind (Figs. 316 and 317).

Mechanism.—It is usually the result of violence acting transversely upon the trochanter major, as from a heavy fall upon the hip. The posterior part of the neck, being weaker than the anterior, first gives way; the whole neck then yields, and the severed head and neck are impacted into the junction of the trochanter and shaft. The majority of these cases are thus primarily impacted, continuation of the violence producing disimpaction, coupled either with detachment of one or

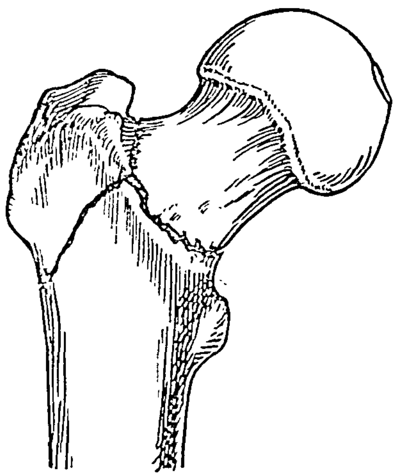


Fig. 316. — Intertrochanteric Fracture of Cervix Femoris. (Semi-diagrammatic, from the Front.)

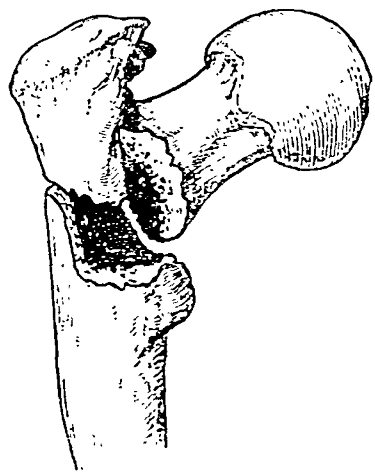


Fig. 317. — Intertrochanteric Fracture of Neck of Femur, seen from Behind. (College of Surgeons Museum.)

The head and neck are depressed, and the trochanter major drawn slightly upwards.

both trochanters, or with comminution of the great trochanter; at least three, and perhaps four, fragments are thus produced (Fig. 317). Disimpaction may also follow at a later date from the rarefaction associated with the early stages of repair or from injudicious manipulation; and thus the shortening, which may at first be slight, often increases at the end of a few days. The upper fragment remains in the acetabulum, whilst the lower end is drawn up and everted.

Union of the fragments is much more certain in this variety than in the transcervical, and it is often accompanied by a considerable development of callus, which may subsequently impair the movements of the limb, whilst secondary bending and late increase of the shortening may occur if the patient walks too soon.

The **Signs and Symptoms** of the transcervical and intertrochanteric fractures may be contrasted.

(*a*) The signs of *local trauma, viz.* pain, bruising, and swelling, may be present in both; but whilst slight in the transcervical variety, they are often very marked in the intertrochanteric.

(*b*) *Crepitus* is evident in the unimpacted forms of each; but it is unnecessary and, indeed, extremely unwise to elicit it by forcible manipulation, especially in the transcervical variety.

(*c*) *Loss of power* is perhaps more marked in the intertrochanteric form than in the transcervical. Cases of the latter in which the patient has been able to walk into hospital some days after the accident are not unknown, and are probably due to impaction.

(*d*) *Eversion* is a most characteristic feature in both varieties, the limb lying absolutely helpless on its outer side, except in the adduction variety of transcervical fracture. This displacement is accredited to the natural weight of the limb, to the greater fragility of the back of the cervix, causing it to be more comminuted than the anterior surface, and, lastly, to the greater power of the external rotator muscles.

(*e*) *Shortening* is slight in the early stage of transcervical fractures, and much greater in the intertrochanteric, even reaching to $2\frac{1}{2}$ or 3 inches. It is indicated by displacement of the trochanter upwards, due allowance being made for the position of the limb as regards abduction or adduction.

(*f*) The *position of the great trochanter* is of the greatest importance. It is raised above its ordinary level, and displaced backwards owing to eversion of the limb; and it is approximated to the middle line of the body.

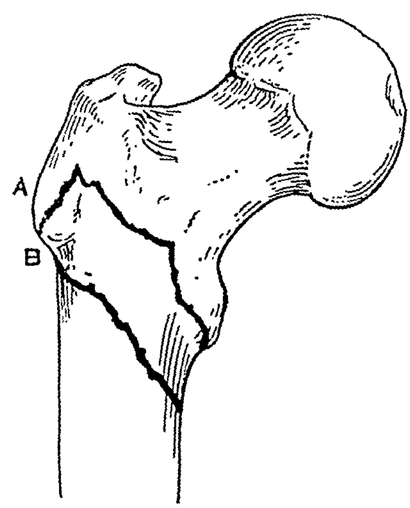


FIG. 318.—A, PERTROCHANTERIC FRACTURE OF FEMUR; B, SUBTROCHANTERIC FRACTURE.

Diagnosis.—A *severe contusion* of the hip, which may be associated with marked eversion, is known from a fracture by the absence of shortening and crepitus; there is no displacement of the trochanter, which rotates in a normal manner. The shortening which sometimes follows, owing to subsequent atrophy of the neck, may, however, complicate matters. In a *dislocation* the head of the bone can be felt in an abnormal position, and hence no difficulty should be experienced in its recognition. In *chronic osteo-arthritis* of the hip a patient may fall and present for examination a limb with definite shortening and marked bony crepitus. It will be found, however, that there is no acute eversion, pain, or loss of power, whilst the existence of similar disease in other joints may assist the surgeon. Moreover, osteo-arthritis of the hip usually results in prominence of the trochanter, and not in flattening, as occurs after fracture; the fascia, too, above the trochanter is never relaxed in osteo-arthritis, always in fractures.

3. **Fracture through the Great Trochanter** (the *pertrochanteric* frac-

ture of Kocher) closely resembles the intertrochanteric fracture, the lesion running from the inner and under part of the neck obliquely upwards and forwards through the base of the trochanter (Figs. 318, A, and 319). The lower fragment is displaced upwards and everted, and its upper edge can often be felt distinct from the top of the great trochanter, which does not move on rotation of the limb; there is also much thickening about the trochanter, and pain on pressure over it. This injury needs to be carefully distinguished from—

4. The *subtrochanteric* fracture, which encroaches on the upper end of the shaft. In this both trochanters are included in the upper fragment (Fig. 318, B), which is flexed by the ilio-psoas and abducted,

FIG. 319.—FRACTURED NECK OF FEMUR WITH SEPARATION OF LESSER TROCHANTER.

whilst the lower fragment is drawn up on its outer aspect and behind it, with considerable shortening and complete eversion.

Treatment.—In those fractures of this group in which the element of coxa vara is not great, and in which the fracture tends to be transverse, immobilization after reduction in a Whitman's plaster may be sufficient, but in most cases continuous traction after reduction has been effected under anæsthesia is probably the ideal. Traction may be exerted through strapping applied to the skin, but better still is a Steinmann's pin driven through the lower part of the femur just above the condyles. The limb is set up in a Thomas's splint and traction, which may require to be considerable as a start (some twenty pounds), instituted.

This should be maintained for about three months, at the end of which time a walking caliper splint is used for a further similar period

5. **Fracture of the Great Trochanter** is rare, and always due to direct violence; in the young it occurs as an epiphyseal lesion (Fig. 320). The trochanter, or a portion of it, is separated from the rest of the bone without any loss of the continuity of the shaft. Independent movement of the fragment with crepitus is usually obtainable; and if the displacement is at all marked, an operation to fix it should be undertaken.

6. **Fracture of the Lesser Trochanter** results from muscular violence and is associated with pain over the inner and upper part of the thigh and inability to flex the thigh when sitting down. Treatment consists in immobilizing the thigh in flexion almost to a right angle and in internal rotation for a month.

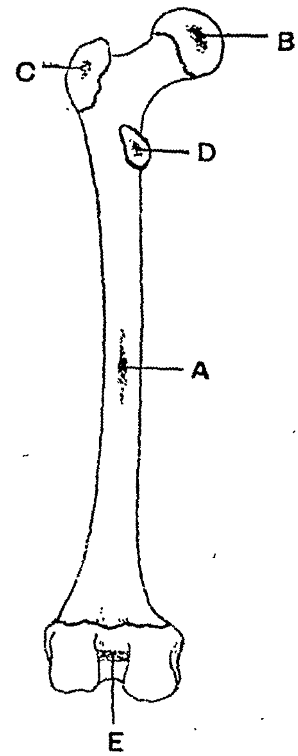


FIG. 320.—CENTRES OF OSSIFICATION OF FEMUR.

A, For shaft, eighth week of intra-uterine life; B, for head, first year, fusing with shaft at eighteenth year; C, for great trochanter, third year, fusing with shaft at eighteenth year; D, for lesser trochanter, twelfth year, fusing with shaft at eighteenth year; E, for lower epiphysis, at birth, fusing with shaft at twentieth year.

Fractures of the Shaft of the Femur are extremely common in spite of the apparent strength of the bone. Any part may be involved, particularly the centre, whilst they occur at the lower end more frequently than at the upper. In the latter situation they are usually due to indirect violence, whilst at the lower end they generally result from direct injury; either form of violence may lead to a fracture about the middle of the bone, and radiography has shown that spiral fractures are by no means uncommon. Exact diagnosis is sometimes difficult, owing to the amount of swelling from hæmorrhage, and to the muscularity of the part.

In almost every case *displacement* occurs, the direction and amount of which depend not only on the line of fracture, but also on the situation. In the *upper third* (Fig. 321), the small upper fragment is usually tilted forwards by the ilio-psoas, and abducted and everted by the gluteus minimus and external rotators; whilst the lower fragment is drawn upwards and to the inner side of the upper by the hamstring and adductor muscles, marked eversion also resulting, partly from the weight of the limb, and partly from the action of the adductors; but such a complicated displacement is not always present.

In the *middle third*, if due to indirect violence, the line of fracture usually slants from above downwards and backwards, causing a simple

overriding of the fragments or an angular deformity. The lower fragment is drawn upwards and inwards, either in front of or behind the upper fragment, and is usually everted. The upper fragment is sometimes tilted forwards. If due to direct violence, the fracture is more or less transverse, often comminuted, and any form of displacement may then occur. In either case there is extensive laceration of the quadriceps extensor muscle, and the sharp end of either fragment may be caught in its fibres, and reduction of the deformity thereby hindered. Considerable hæmorrhage follows, and a large collection of fluid blood around the ends of the bone sometimes impedes reduction and repair.

In the *lower third* the fractures which arise from direct force are transverse; the lower fragment may then be tilted backwards by the gastrocnemii muscles (Fig. 322),

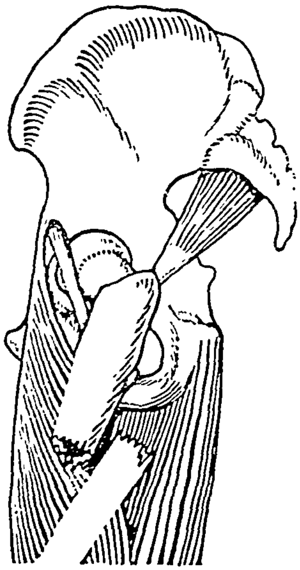


FIG. 321.—FRACTURE OF UPPER THIRD OF FEMUR, SHOWING DISPLACEMENT OF BONE.

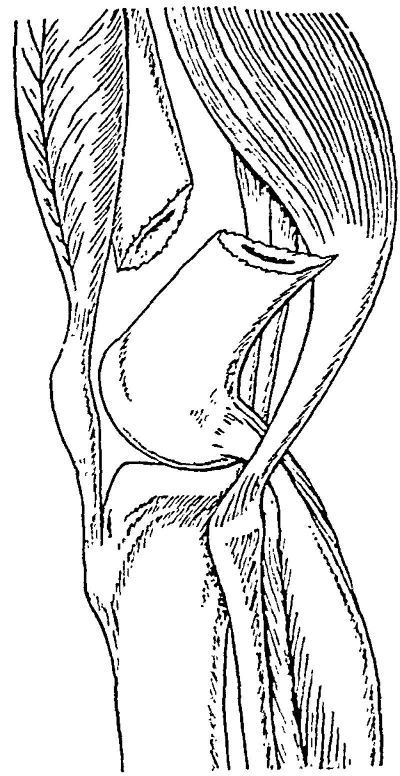


FIG. 322.—FRACTURE OF LOWER THIRD OF FEMUR, SHOWING DISPLACEMENT OF LOWER FRAGMENT BACKWARDS.

and compress or rupture the popliteal vessels, perhaps causing gangrene. Oblique or spiral fractures from indirect violence, sloping from above downwards and forwards, are also met with; the upper fragment is driven into the substance of the quadriceps muscle, and may become fixed in it, projecting immediately beneath the skin close to the upper border of the patella, whilst the lower fragment is drawn up behind. If such a case is left unreduced, non-union is likely to ensue; the knee-joint is generally penetrated by the lower end of the upper fragment.

Open (Compound) Fractures of the femur have been only too common during the past few years as the result of military activity, and may result from any form of gunshot wound. A rifle bullet travelling cleanly inflicts little damage on the soft tissues, and may traverse the cancellous structure of the femur near the neck or close to the knee without causing any solution of continuity; if, however, it hits the compact shaft, a complete fracture results, often with great comminution.

In civilian practice open fractures of the femur are generally the result of direct violence, such as street, railway, or machinery accidents; they are associated with much laceration and often with severe infection of the overlying soft tissues, and hence the patients, when first seen, are often in a condition of grave shock.

The history of these cases is very similar to that of all open fractures (p. 556); the peculiarities depend on the central position of the bone in the limb, rendering drainage and accurate fixation of the fragments more difficult. Consequently, infective troubles in the wound and of the bone are frequently observed. Necrosis is not uncommon, and, owing to the density of the compact bone, the sequestrum is long in separating; even when union occurs it may be associated with much shortening and deformity, and the knee may be stiff. Sinuses may persist for long, and the convalescence is often very slow.

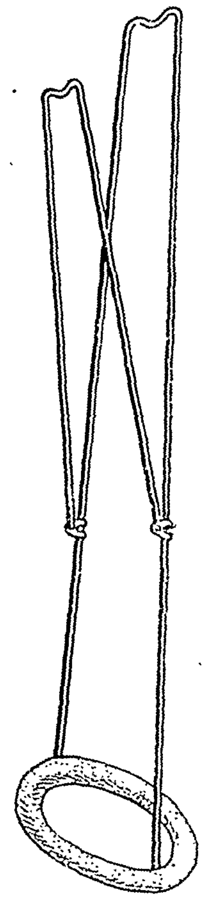


Fig. 323.—Thomas's Splint with Movable Leg-Piece to permit Movement of Knee-Joint.

The Treatment of Fractures of the Shaft of the Femur.—I. **Prolonged Extension** is necessary in some fractures of the upper end, and in almost all fractures of the shaft, if the fragments are to be satisfactorily replaced and shortening prevented. Powerful muscles are attached to the fragments, and to counter their activities effective extension is needed.

In the past Thomas's splint (Fig. 323) has held pride of place in the treatment of these fractures, but from all points of view Braun's is the more valuable. It consists essentially of an angled frame, the part designed to support the thigh being set at about 30 to 40 degrees, so that the femur is always flexed to that extent (Fig. 340). Traction can be readily exerted in the line of femur in the manner shown in figure without any obstruction from the lower leg. The limb is supported by flannelette bandages running between the limbs of the splint. Counter-extension is provided by using the body weight, the lower end of the bed being raised on blocks. But in order to prevent the frame from sliding down it should be fixed to the foot of the bed. Over the head of the bed and attached firmly to it should hang a

support, so that the patient may raise himself up with his arms. Traction may be exerted by one of three methods, old means such as Sinclair's foot-piece being really only of historical interest.

(*a*) *By Adhesive Plaster.* In this method wide strips of adhesive plaster are fixed, one on the inner side of the thigh and one on the outer. In order more easily to mould the strapping to the limb it is beneficial to make a number of oblique cuts along the whole length (Fig. 324). The ends of the strapping are carried beyond the knee and attached to a spreader, which consists essentially of a square of

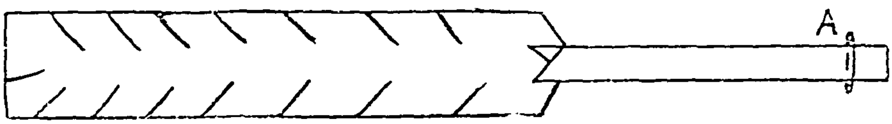


FIG. 324.—METHOD OF CUTTING AND FOLDING THE STRAPPING IN APPLYING EXTENSION.

wood with a hole drilled through the centre (Fig. 325). Through this a length of cord is threaded, and this is carried over the pulley at the end of the splint and a weight attached to its end. To prevent the strapping slipping it is further maintained in position by spirally arranged strips of strapping placed over it, which, however, never surround the limb, so that there shall be no obstruction to the circulation. Similar strapping extension is applied to the lower leg.

(*b*) *By Unna's Paste.* In this method the principle is exactly similar, but the extension is exerted through calico strips fixed to the thigh by Unna's paste.

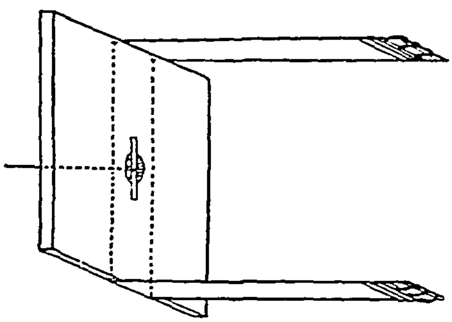


FIG. 325.—METHOD OF ARRANGING STRAPPING ON 'SPREADER.'

(*c*) *By Skeletal Traction.* Here traction is exerted directly through the bone by a Steinmann's pin or Kirschner's wire passed either through the lower end of the femur in fractures of the shaft or upper end, or through the tibial spine when the lower end is involved (Fig. 326). The ends of the pin or wire are connected to a stirrup, and through this extension is exerted. Of all forms of extension this is by far the most admirable and satisfactory. A more powerful pull can be exerted, there is no strapping to be pulled gradually down the leg, and in cases of compound fracture there is no strapping to interfere with the dressing of a wound.

In fractures of the femur an initial extending force of some fifteen to twenty pounds is required, but when reduction has been effected for a week or so this may be reduced. Where the upper end of the femur is fractured the limb must be put up in a position of full abduction, and in order to prevent rotation of the pelvis it is advisable to fix the sound leg in a similar position. Where the fracture is in the upper

part of the shaft less abduction is necessary, and in the lower end the limb should be fixed in a straight position. Any tendency for external rotation to occur can be prevented by a loop of bandage attached to the outer part of the pin and fixed by a piece of cord over a pulley attached to a Balkan beam, which consists of a wooden overhead bar attached by vertical posts at either end of the bed resting on solid floor supports. Foot drop is prevented by attaching some strapping to the sole and fixing to its upper end a cord passing over a pulley-system attached to the Balkan beam. If there is any loss of the normal anterior curvature of the femur, a small pad placed behind the site of fracture will remedy this, and similarly in fractures of the lower end of the femur any valgus deformity is counteracted by a rubber pad placed between the frame of the Braun's splint and the inner aspect of the thigh.

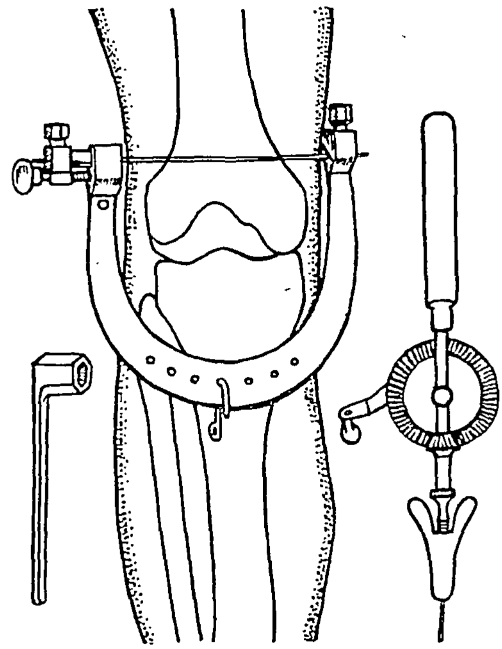


FIG. 326.—DIAGRAM OF KIRSCHNER'S WIRE INSERTED INTO THE LOWER END OF FEMUR.

The heavy stirrup is necessary in order that the wire may be held under tension after it has been inserted. A drill for inserting the wire is also shown.

The mattress on which the patient lies may advisably be of the divided type (Fig. 327), so that removal of the central portion permits of access to the back and buttocks, which can thereby be better protected from bedsores, and bedpans, etc., can be more easily employed. From the start the patient is encouraged to move the hip-joint by hoisting himself with his arms into a position in which the hip is flexed, by means of the support above the bed. Passive movements of the knee-joint are carried through daily and active ankle movements are encouraged. None of these movements will in any way alter the position of the fragments, which are well held by adequate extension and support, and, in addition, the joints do not become stiff or the muscles wasted, rendering subsequent recovery of function far quicker. If the fracture is set up in such a way as to allow no joint movements, in all except young persons the joints will rapidly become stiffened, and many weeks of subsequent

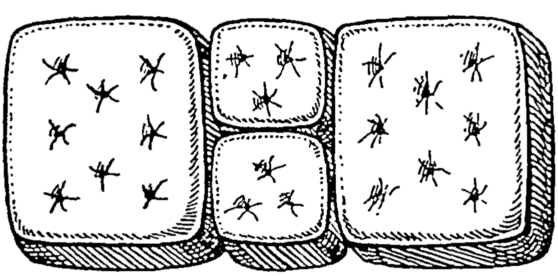


FIG. 327.—DIVIDED MATTRESS FOR TREATMENT OF FRACTURES OF THE PELVIS, FEMUR, ETC.

physical treatment will be required to restore anything like normal mobility.

Traction in these cases needs to be continued for from two to three months, and it is better in the later weeks to remove the pin and replace the extension by strapping to avoid any possibility of infection occurring. After some weeks the pin will have become loosened by bony absorption round it, and the slight movement present is liable to encourage bacteria to pass into the substance of the bone.

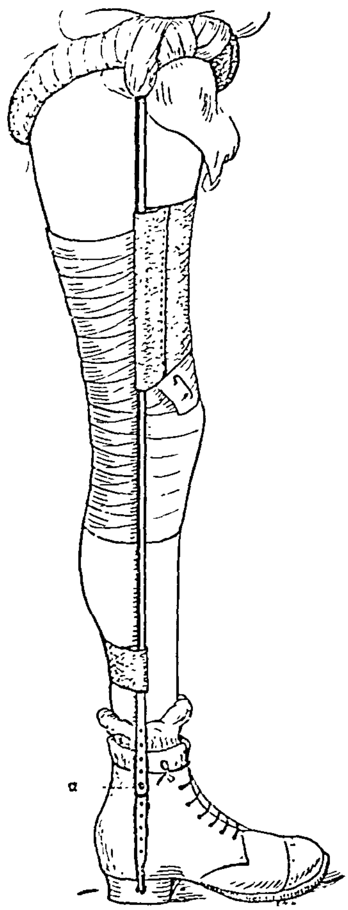


FIG. 328.—WALKING CALIPER FOR USE AFTER FRACTURES OF THE LOWER EXTREMITY.

a indicates the position of a screw which fixes the overlapping ends of the two segments of which the appliance consists, thereby modifying the length for varying patients.

Following this a further three months is required in a walking caliper before weight-bearing is allowed, but in all cases the procedure must be controlled by X-ray examination.

When the fracture has united it is undesirable to put a Whitman's plaster on and allow the patient to get about, because all the good that has been done in keeping the joints mobilized will be undone.

In fractures through the lower end of the femur the lower fragment will, if the line of fracture is above the points of origin of the gastrocnemii, be rotated backwards. The case should be treated similarly on a Braun's splint, but skeletal traction should be exerted not through the lower end of the femur, as on account of the position of the fracture there is the danger of drawing a pin placed below it through the knee-joint, but through the tibial spine. Movement of the hip can be commenced at once, but those of the knee must not be attempted for some two or three weeks. Traction is maintained for about five or six weeks, but the pin should be removed after three weeks, as if traction is exerted on it for longer there is the danger of producing an unstable knee-joint as the weight acts indirectly through the lateral ligaments. At the end of this time a weight-bearing caliper should be used for a further similar period (Fig. 328). Occasionally in oblique fractures in this region reduction is difficult, and open operation may be required.

In children up to ten or twelve years of age, Bryant's plan of treatment (Fig. 329) is excellent. It consists in slinging up the limb at right angles to the body from an overhead beam, utilizing the child's

weight as the extending force. Adhesive plaster extension is applied to both limbs; the sound leg is tied up out of the way; the injured limb may be tied to the beam, or a weight passing over a pulley may be utilized. In any case the child's pelvis should just be lifted from the mattress so that the body weight really acts; the insertion of an unnecessary pillow negatives the object desired. If abduction is also needed, the overhead beam should be set across the bed, and fixation effected as suggested above. This position is maintained for four or five weeks, and then the limb is loosened and massage and movements permitted, but the patient is not allowed to walk until a calliper has been fitted.

An alternative method consists in making use of strapping traction,

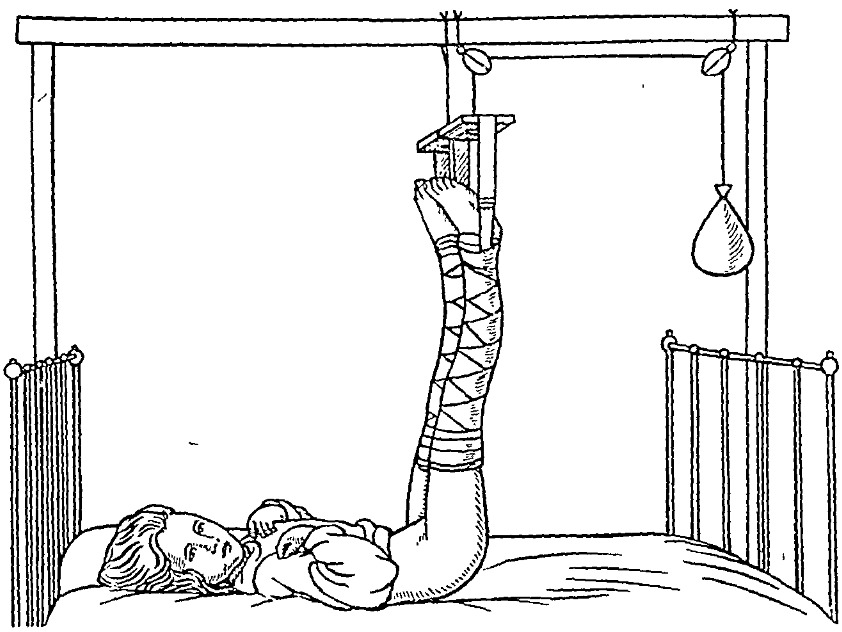


FIG. 329.—BRYANT'S METHOD OF EXTENSION FOR TREATMENT OF FRACTURE OF THE FEMUR IN SMALL CHILDREN.

The right leg is fractured, and has the weight attached to it; the left leg is merely tied up to keep it vertical and out of the way.

but instead of using a Thomas's or other splint the limb is enveloped in a plaster cast, which can easily be suspended from a Balkan beam by means of several plaster loops included in it. The extension is maintained by passing the cord over a pulley at the bottom of the bed and attaching a suitable weight.

For the obstetric fracture which occurs in babies the best treatment is to apply a small padded splint on the outer side of the thigh. The thigh should be kept abducted.

II. **Operative Treatment** for fractures of the shaft of the femur is occasionally necessary. Surrounded as it is by a muscular bed, sometimes of great thickness and strength, it is almost impossible to influence the alinement of the fragments into which the femur is broken if extension fails in this object. Short splints and pads are

of little use when opposed to powerful and healthy muscles, and hence, in spite of all a surgeon's skill and effort, operation is sometimes required. One must, however, repeat the warning that it is a serious procedure, and must not be resorted to without due consideration or by those who are not expert in bone surgery.

In the **upper third** exposure of the fracture is made through an incision along the posterior aspect of the great trochanter downwards for a sufficient distance to enable the quadriceps to be turned forwards and the biceps backwards; the lower fibres of the gluteus maximus may need to be divided. Fixation is best secured by a plate with six or eight screws; it may be possible to reach the anterior as well as the posterior surface, and to this a second plate may be secured.

In the **middle third** the incision should be made to the outer aspect of the rectus femoris muscle, cutting through the substance of the vastus externus. Plates or wire are best adapted to secure alinement; with a very oblique fracture a couple of silver wire mattress sutures is perhaps the best means of fixation.

In the **lower third** operation is best undertaken through an incision on the outer side in front of the ilio-tibial band; but not unfrequently it is desirable also to have an incision on the inner side extending up from the internal condyle. Plates can then be fixed on both sides of the bone after reduction of the deformity.

Fractures of the lower end of the femur are of several different types.

1. **T- or Y-shaped Fracture of the Condyles.**—In this a transverse fracture close to the knee is complicated by a fissure which runs into the joint, separating the two condyles; or more frequently a Y-shaped fissure may start from the intercondyloid notch. The condition is very painful; the joint is distended with blood, the bone may feel broader than usual, and crepitus may be detected on grasping the knee. Comminution is not uncommon. **Treatment.**—Reduction is best effected by exerting traction through a Steinmann's pin traversing the tibial spine, the limbs being set up on a Braun's splint. Careful moulding of the fractured condyles will often yield a good result; but if this fails operation to fix the fragments by screws, nails, plates, or bone pegs will be necessary.

Traction should be maintained a month to six weeks, and a plaster cast to the whole of the limb then applied with the knee in extension. This is kept on for another month.

2. **Separation of either Condyle** usually results from direct violence, but occasionally has followed such an indirect injury as catching the toe against the kerbstone. There is no shortening, but the leg may be deflected towards the side injured, and the knee-joint be full of blood. The fragment which is tilted backwards by the gastrocnemius may move separately from the shaft, and give rise to crepitus. **Treatment.**—Reposition is sometimes effected by flexion of the limb and manipulation, but in healthy adults treatment by operation is often desirable, the fragment being fixed by screws, bone-pegs, or plates.

3. **Separation of the Lower Epiphysis of the Femur** (Fig. 320, E) is not a rare accident, and is frequently due to a child sitting behind a

cab and getting a leg entangled between the spokes of the revolving wheel. The limb is thus forcibly hyper-extended at the knee, and the epiphysis becomes detached and is carried forwards. The lower end of the diaphysis projects behind, and may compress the popliteal vessels; gangrene has been known to result. As in the humerus, the line of separation does not always correspond to the epiphyseal line, but sometimes encroaches on the shaft. Suppuration occurs in a fair proportion of the cases. **Treatment.**—Reduction is effected by an assistant making traction on the tibia in the line of the limb so as to stretch the quadriceps; then the thigh is gradually flexed by the surgeon, standing above and with both hands clasped beneath it. The epiphysis is by this means restored to its normal position, and the limb may then be splinted, *e.g.* plaster, with the knee flexed to about 60 degrees. Walking should not be permitted for at least six weeks.

Fractures of the Patella.

The patella is broken either by muscular force or by direct violence, and the conditions produced are so different that a separate description is necessary.

1. **Fractures by direct violence** may traverse the bone in any direction, but are most often vertical or star-shaped, and frequently comminuted. They are usually mere fissures without displacement, owing to the aponeurosis or capsule of the bone remaining intact. There is a good deal of subcutaneous bruising, and perhaps some effusion into the joint, whilst on careful palpation the fissure may be felt, and crepitus occasionally detected. **Treatment** consists in keeping the limb at rest on a back-splint, and perhaps applying evaporating lotions. Massage and passive movements are commenced early where there has been much hæmorrhage into the joint, and the use of a walking caliper permits the patient to get about at an early date. Operative measures are rarely required.

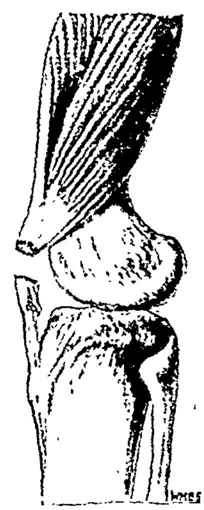


FIG. 330.—FRACTURE OF PATELLA, WITH SEPARATION OF FRAGMENTS.

2. **Fractures due to muscular force** are always transverse, usually complete, and, when they involve the fibrous aponeurosis, associated with considerable displacement.

Mechanism.—When the knee is semi-flexed, the patella is poised upon the front of the condyles of the femur, resting upon the middle of its articular surface; in this position any sudden and violent contraction of the quadriceps, as in attempting to recover one's equilibrium after having slipped, takes the bone at a disadvantage, and may succeed in snapping it (Fig. 330). Possibly in some people there is a predisposing weakness, as cases are not rare in which the other patella is broken at a later date. The fragments may be almost equal

in size, but the lower is often the smaller; either of them may be again divided vertically, or comminuted (Fig. 331).

The **Signs** of this fracture consist of loss of power in the limb, pain, distension of the joint with blood, and separation of the fragments, which can be readily felt and sometimes seen. This displacement is due to unopposed muscular action, and is not excessive unless associated with rupture of the lateral expansions of the vasti muscles. Union by bone is rarely obtained apart from operation, owing to the separation of the fragments, and the carrying in of loose tags of the fibrous aponeurosis or capsule, which yields at a different level to the bone. Fibrous union is the usual result, and when this is short and strong it is quite satisfactory; but more commonly the bond of union slowly yields when the limb is used, so that the two fragments are once again separated, merely a bridge of fibrous tissue intervening, the joint being left in a weak state, and the power of active extension of the leg much impaired or lost (Fig. 332).

FIG. 331.—FRACTURED PATELLA.

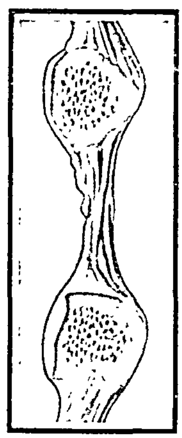


FIG. 332.—FIBROUS UNION OF FRAGMENTS OF PATELLA. (KING'S COLLEGE HOSPITAL MUSEUM.)

The **Treatment** of these fractures may be grouped under two headings, *viz.* either by the use of simple retentive apparatus, or by open operation.

1. *Simple retentive apparatus* may be employed in cases where the fragments are not widely separated, and can be readily brought into contact, or where the patient is not a good subject for operation.

A posterior splint extending from the gluteal fold to the foot may be used. The displaced fragments may be approximated by means of suitable pads. At the end of three weeks a ham-splint is substituted and the patient allowed to get about on crutches with his knee in a rigid splint, which can be easily removed for daily massage and passive movements. At the end of five or six weeks

active movements are permitted. It is probable that only fibrous union is obtained by this method of treatment, but this is satisfactory and strong enough if the patient can give the time (six to twelve months) to ensure its solidification. The strength of this fibrous union is best illustrated by the fact that if the bone gives way a second time, the lesion takes place through the bony, and not through the fibrous tissue. When, however, the patient has to work for his living, it is essential that repair should be established at as early a date as possible, and this can only be secured by operative treatment.

2. The *open plan of treatment*, originally advocated and perfected by Lord Lister, is undoubtedly the best, in that it permits of the removal of the tags of fascia and aponeurosis, which always intervene. It

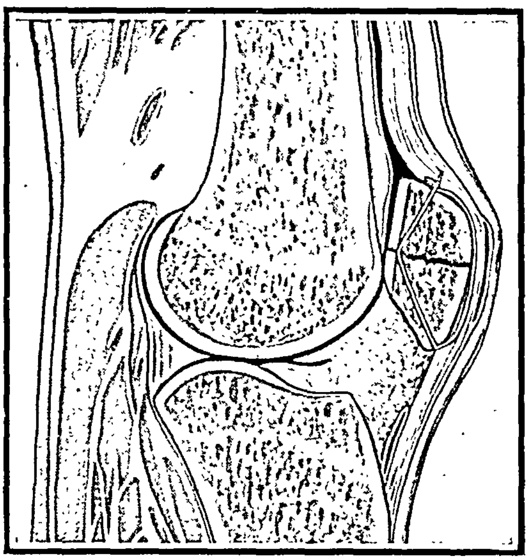


FIG. 333.—LISTER'S PLAN OF SUTURING PATELLA BY OPEN OPERATION.

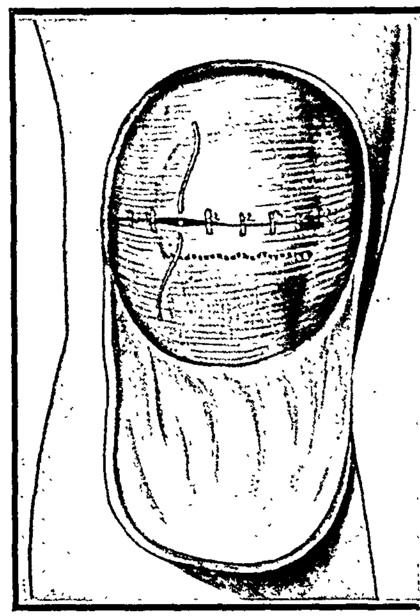


FIG. 334.—RESTORATION OF TRANSVERSE FRACTURE OF PATELLA BY CATGUT SUTURES APPROXIMATING THE FIBRO-PERIOSTEUM.

may be wise to delay operation for a few days in order that the joint may recover from the immediate effects of the injury.

A horseshoe-shaped flap is turned down, exposing the fractured ends of the bone, which are cleared of all clot and fibrous shreds. Tracks for the wire sutures are now made by a drill, extending from the upper and lower ends through the centre of the bone, so as to emerge on the fractured surface just in front of the articular cartilage (Fig. 333); should the drill emerge at different levels on the faces of the fragments, cartilage or bone must be chipped away to make a channel in which the wire may lie, so that the two fragments are exactly level, with no inequality of the articular cartilage. A stout sterilized silver wire is then passed; the bones are brought into apposition, and the wire twisted into a knot or loop, which is hammered or pressed down into

the tendinous or periosteal tissue over the upper fragment, so as t keep it from projecting under the skin and causing irritation. A second wire is sometimes needed in order to prevent rotation of th fragments. The wound is closed, and the limb kept on a ham splin (Fig. 335). In healthy adults passive movement may commence i

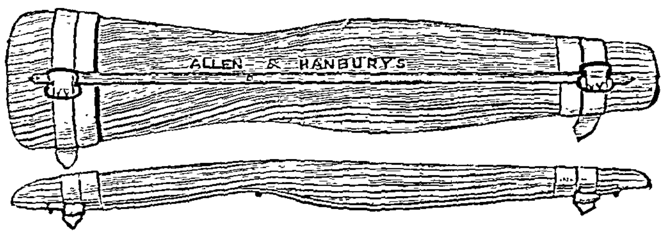


FIG. 335.—HAM SPLINT, WHICH IS USED AFTER OPERATION FOR FRACTURED PATELLA.

ten days, and by the end of a fortnight the patient is allowed to wal in the simpler cases; but in complicated fractures and in elderly peopl it is better to keep the limb immobilized for a little longer period.

Of recent years there has been a considerable reaction against th method of burying silver wire in the tissues, especially when passin through a bone exposed to tension or movement. The wire may become disintegrated and break, or rarefactive osteitis may be caused thereby. Surgeons at the present time are rather favouring methods which depend on absorbable ligatures in the form of unchromicized catgut. The joint is opened and cleansed of blood-clot, and loose fibrous tags are removed. Antero-

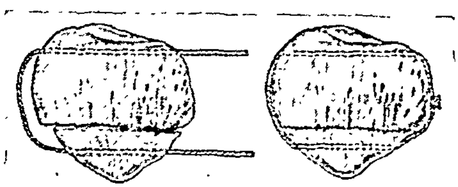


FIG. 336.—DIAGRAM SHOWING HOW A FRACTURED PATELLA MAY BE WIRED IN A HORIZONTAL MANNER.

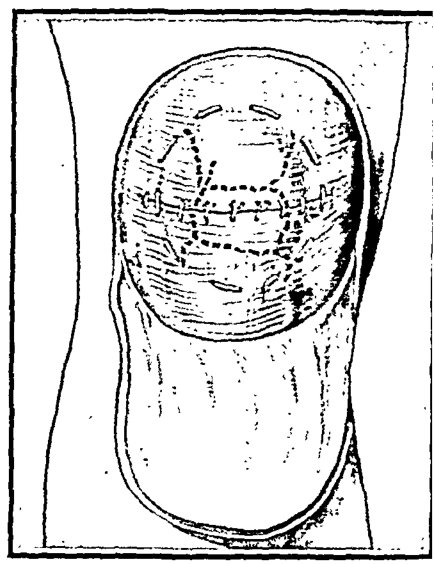


FIG. 337.—COMMINUTED FRACTUR OF PATELLA TREATED BY INTER RUPTED SUTURES.

posterior *cerclage* of the bone with two or three strands of stout catgu is undertaken, and after bringing the fragments into apposition b manipulation these are firmly tied (Fig. 337). The rent in the fibro periosteum and lateral tendinous expansions is also closed by sutures In cases where there is but little displacement, the cerclage suture

may be omitted; in others, especially when the bone is in more than two fragments, a circumferential cerclage may be desirable as an added precaution. After-treatment is much as indicated above, but active movements are perhaps commenced a little later, in that catgut is being relied on, and not silver wire, to maintain the co-apposition of the fragments until the time when osseous union is fully established.

In cases which have not been operated upon, and where fibrous union and an unstable joint have resulted, it may be impossible to get the fragments together by open operation. Much, however, can be achieved by taking a strip of fascia lata and passing it through the lower part of the quadriceps tendon, and then through the ligamentum patellæ, as practised by Hey Groves (Fig. 338). This operative procedure has a definite stabilizing effect on the joint, and patients can often resume their occupations.

If the fragments cannot be brought absolutely together, the same treatment may be adopted, and the patient allowed to get about with a loop of silver wire between the fragments; the quadriceps is stretched by this means, and a subsequent operation may prove successful in gaining bony union.

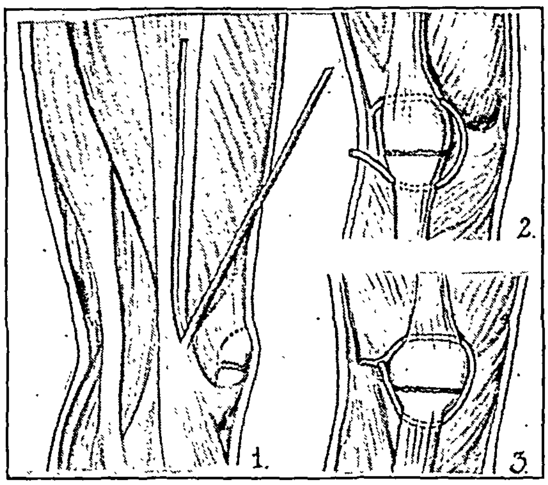


FIG. 338.—METHOD OF STABILIZING THE PATELLA IN AN OLD-STANDING CASE WITH FIBROUS UNION.

A strip of fascia lata is turned down and made to encircle the patella, passing the quadriceps extensor tendon above, and through the ligamentum patellæ below.

Fractures of the Leg.

Fractures of the Tibia Alone.—Several varieties are described.

(*a*) **Fracture of the Spine** on the articular surface is accompanied by much bleeding into the joint. If the displaced fragment is not replaced, permanent disability will result. Usually this can be effected following aspiration of the joint under full aseptic conditions by extending it to the full and maintaining the extension for two months. Until the swelling has subsided it is desirable to apply a pressure bandage and a back splint, this subsequently being replaced by a plaster cast with a walking-iron. Occasionally open operation is required, when the fragment will be either seated firmly down into its bed or removed.

(*b*) **Fractures of the Condyles.**—Either one or both condyles may be fractured. If the lateral one is fractured, there will be a certain amount of abduction deformity, and if the medial one adduction is present. Reduction is effected by strong traction in a longitudinal

axis with an element of abduction or adduction opposite to that of the deformity, the limb being put up in plaster in extension for two months. Where both condyles are affected strong traction exerted through a pin passed through the os calcis is required. This is maintained for six weeks or so, the limb then being put up in a spica with a walking-iron for a further two months. Occasionally open operation and fixation of the fragments with a peg or nail are required.

(*c*) **Fractures of the Shaft of the Tibia** are usually caused by direct violence. They are transverse in the upper part of the bone and oblique

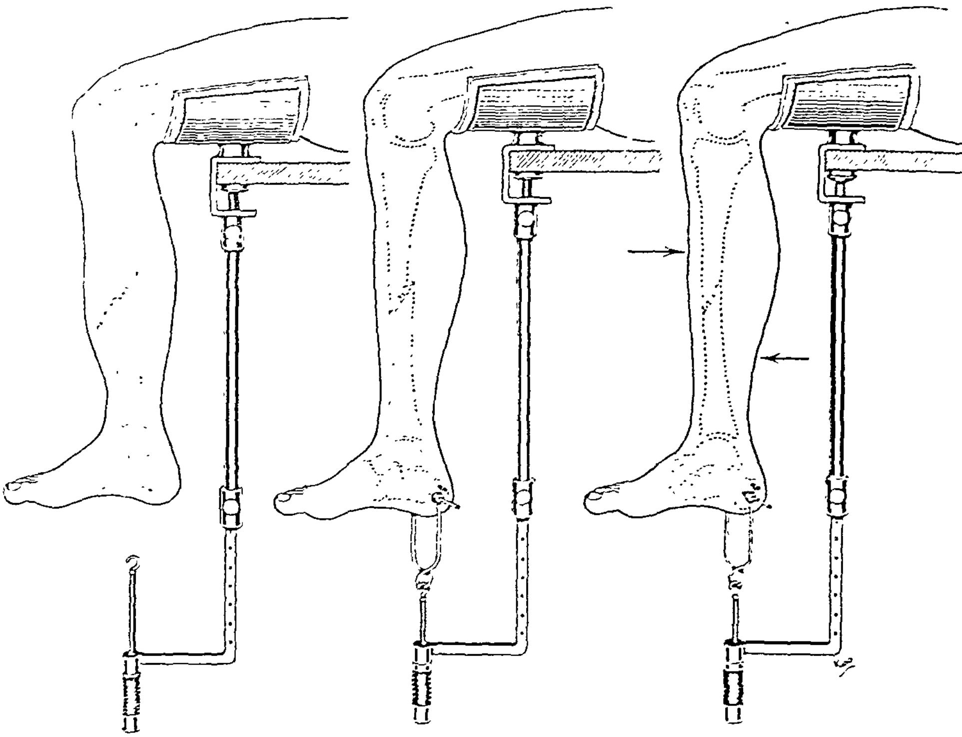


FIG. 339.—REDUCTION OF A FRACTURE OF THE SHAFT OF THE TIBIA BY TRACTION WITH A PIN THROUGH THE OS CALCIS. (WATSON-JONES.)

below. The fracture is diagnosed by feeling an inequality on running the fingers along the shin, together with pain at this spot on firmly grasping the bones above and below. There is often but little displacement, since the fibula acts as a splint, but the lower end of the upper fragment, which is usually pointed, is tilted forwards by the action of the quadriceps, and may pierce the skin. Reduction is usually easy to effect by traction and manipulation, although occasionally in a transverse fracture it is necessary to pass a Steinmann's pin and exert strong traction through this before the slight overlap which is present can be reduced and the ends disimpacted (Fig. 339). A plaster cast extending to the knee is then applied, and if there is much

bruising it is best to bivalve this until it has subsided. If the cast is then loose, a new one is applied fitted with a walking-iron and left on for two months or more.

(*d*) The **internal malleolus** is occasionally separated as the result of direct injury, apart from any other osseous lesions, constituting what is known as *Wagstaff's fracture*. There is comparatively little displacement, but the malleolus is loose, and crepitus can usually be obtained on moving it backwards and forwards. Union by fibrous or osseous tissue ensues, but often in a more or less abnormal position, in consequence of which the integrity of the ankle-joint is disturbed, and weakness or lameness may follow. **Treatment** consists in bringing the fragment into position by inversion of the foot and manipulation, and maintaining this by strapping or plaster of Paris for some weeks; massage and gentle movements are, of course, allowed after a week or ten days, but only if the movements are painless. Failure in reposition of the fragment necessitates its fixation by operation; a bone-peg is the best to use.

Fractures of the Fibula alone are by no means uncommon. In those of the shaft there is usually a minimum of deformity and little pain. They are due to direct violence. It suffices to apply a plaster cast to the lower leg, allowing this to remain on with a walking-iron for six weeks. When direct violence is applied to the inner aspect of the knee-joint the head of the fibula may be fractured with considerable displacement, and perhaps injury to the external politeal nerve. Only open operation can effect efficient reduction, and the fragments are maintained in position by wiring. A plaster cast extending to the tuber ischii is applied for six weeks. If efficient reduction of the fracture is not performed, weakness of the knee-joint and often involvement of the nerve will result.

Fracture of both Tibia and Fibula is a very common accident, due to both direct and indirect violence; if to direct violence, any part may be injured, both bones yielding at the same level; but if in consequence of an indirect injury, the tibia usually gives way at its weakest part, *viz.* at the junction of its middle and lower thirds, and the fibula at a higher level. The fractures are often oblique, running in any direction, although the obliquity is most frequently directed downwards, forwards, and inwards. The lower fragment is generally drawn upwards on account of the contraction of the powerful calf muscles, and often rotated outwards from the weight of the foot; hence there is well-marked shortening. The ordinary characteristics of a fracture are very evident, and but little difficulty can ever be experienced in making a diagnosis. The fracture is likely to become compound when due to indirect violence, owing to the sharp end of the upper fragment of the tibia piercing the skin.

The fracture of the tibia has been proved by radiography to be frequently of a spiral character, and is then probably always due as much to forcible torsion of the limb as to vertical strain. The rotation is an important element, and the shortening is sometimes less marked than in simple oblique fractures; there is frequently some difficulty in getting satisfactory approximation of the fragments, even on opera-

tion, owing to the broken ends becoming engaged in the fibro-muscular tissues around.

Treatment.—In those fractures in which the displacement is minimal or where simple traction is sufficient to produce reduction in a good position—and this especially applies to transverse fractures—it is sufficient to apply a plaster slab extending from the toes to the knee-joint and fix this by turns of plaster bandage. Sometimes where the fracture is higher up it is advisable to include the thigh in the plaster in addition to the lower leg. The foot should be placed as near the right-angle position as is possible, but if dorsiflexion to that extent produces displacement of the fracture it should not be insisted

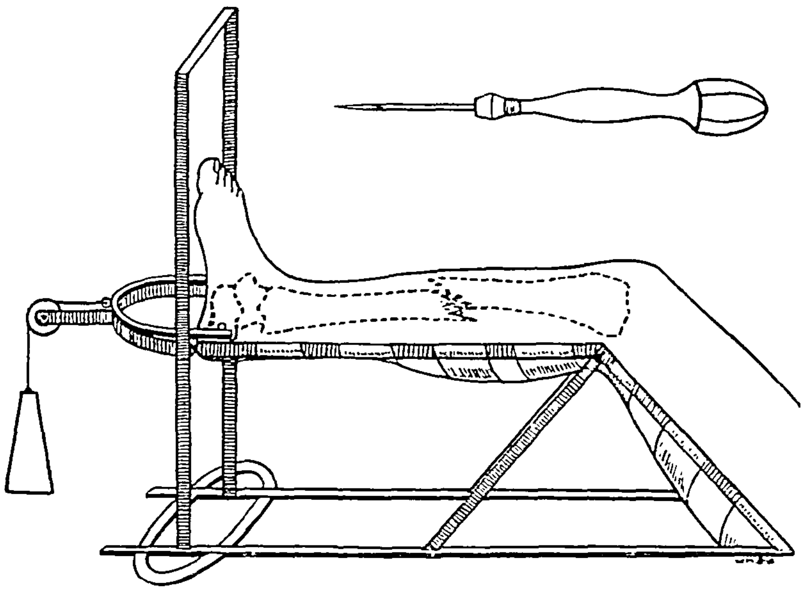


FIG. 340.—BRAUN'S SPLINT.

The leg is supported on flannel slings. Traction is made from a pin passed through the os calcis by the weight which hangs over the end of the bed. Counter-extension is obtained by tilting up the lower end of the bed on blocks. The shape of the splint ensures that the knee is kept flexed, but allows the patient to be propped up in bed with pillows. The pin and its introducer are seen above.

on. It is absolutely essential to keep an eye on the limb for the onset of any swelling subsequent to the application of the plaster, and if more than a minimal amount appears around the toes the plaster must at once be bivalved or even removed to avoid the possibility of gangrene occurring. When the patient is going to be away from observation, it is necessary to bivalve the plaster at the time of its application. The following day the patient is fitted with a walking-iron and is allowed to get about. The plaster should be retained until union has occurred, a process taking three months or more. Often following the removal of the plaster there is some reactionary œdema of the leg, but this can be prevented by applying either Unna's paste or elastoplast before the patient starts weight-bearing. When

following reduction the displacement recurs, some alternative treatment is required. One of two methods may be adopted. The traction may be maintained by means of Steinmann's pin passed through the os calcis, the limb being set up in a Braun's splint (Fig. 340) and supported in its reduced position by a plaster cast applied to the calf and foot. When sufficient callus has formed effectively to prevent any further displacement, usually in some six weeks' time, a walking-iron is applied for a further similar period (Fig. 328). This method should be used for the treatment of compound fractures in these bones, because besides maintaining a reduced position it enables any dressings that may be required to be effectively carried out. However, this method has all the disadvantages of keeping the patient in bed for some time. To avoid this Böhler has devised a very effective form of ambulatory treatment. A pin is passed through the lower end of the tibia and fibula and another through the spine of the tibia. The fracture is reduced by traction exerted through the lower pin, and the limb is then encased in plaster while extension is maintained. When the plaster has set around the projecting ends of the pins, these are held immobilized and thus effectively prevent any recurrence of the displacement. A walking-iron is fitted and the patient enabled to get about. Some surgeons in severe fractures advocate open operation with maintenance of position by some mechanical device, but the cases in which this is required are few.

Fractures in the neighbourhood of the Ankle-joint are usually produced by indirect violence, such as wrenches, twists, slips, or falls on the feet. Lateral displacement of the abduction or adduction type was formerly considered to be the chief cause, but radiography has demonstrated that forced movements of version are even more important and frequently accompany the former—eversion with abduction, and inversion with adduction—and the resulting fractures are correspondingly modified. In addition, when once the tibio-fibular mortice has been impaired, the weight of the body aggravates the mischief, whilst the back-push of the foot may damage the posterior margin of the tibia, causing the so-called marginal fracture which complicates many of the more serious lesions. These accidents should therefore be termed *fracture dislocations of the ankle*.

1. Fractures due to **Displacement of the Foot outwards** constitute by far the largest and most important group. They result from the patient slipping on the inner side of the foot, as from off a kerbstone. The two elements of eversion and abduction enter into and colour the picture, and may be combined in many ways to produce various types of injury.

(*a*) In the *simpler* forms, one or both bones may be broken, but there is no lateral displacement of the foot and astragalus if the inferior tibio-fibular ligament remains intact. When the foot is forcibly displaced outwards, the strain mainly falls upon the internal lateral ligament, and this gives way or the internal malleolus is torn off if the stress is too severe. The astragalus is thereupon driven outwards against the external malleolus, and excess of violence leads to fracture.

When *eversion* is the chief cause of the lesion, the fracture is generally

oblique from above downwards and forwards; it may pass through the malleolus or be situated above it, but, of course, in the latter case there is more deformity.

In the *abduction* type the fibular fracture is more or less transverse, the upper end of the lower fragment being displaced inwards. It is possible for both malleoli to be broken off at their bases and displaced inwards or outwards, but this *bi-malleolar fracture* is very uncommon and of a different character entirely. In the abduction group the fibula is usually broken just above the malleolus, but often somewhat higher. It was to a fracture of this type placed about 3 inches above the tip of the malleolus and associated with injury to the internal malleolus or internal lateral ligament with marked abduction of the foot that the term *Pott's fracture* (Figs. 341 and 342) was originally applied.

When forcible eversion and abduction are combined in producing the fracture, a more complicated type of injury may result, and not unfrequently some degree of comminution may co-exist.

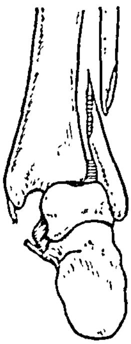


FIG. 341.

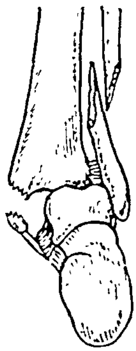


FIG. 342.

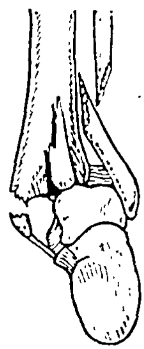


FIG. 343.

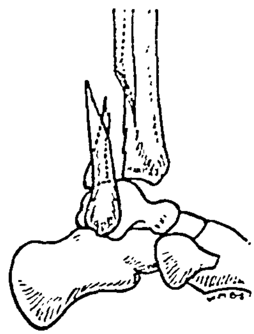


FIG. 344.

FIGS. 341-344.—DIAGRAMS OF POTT'S AND DUPUYTREN'S FRACTURES SEEN FROM BEHIND AND LATERALLY TO SHOW DEFORMITY AND LESIONS IN THE BONES.

(*b*) A much more serious injury is that to which the term *Dupuytren's fracture* (Figs. 343 and 344) has been applied. In this the interosseous tibio-fibular ligament yields more or less completely, or the flake of the tibia to which it is attached is torn off; the foot, carrying with it the lower portion of the fibula and the superficial flake of the tibia, which has been detached, is displaced firstly outwards, and so long as the upper surface of the astragalus does not clear the lower articular surface of the tibia, there is merely lateral displacement with marked abduction of the foot and increased breadth of the ankle. Should the force continue to act, the astragalus may be carried sufficiently outwards to clear the lower end of the tibia, and then an upward and to a less degree a backward displacement is added, causing great eversion of the foot and deformity of the ankle. On the inner side either the ligament or the malleolus may yield. It is often associated with a marginal fracture of the posterior lip of the tibia.

(*c*) In another variety the injury consists in the usual type of fracture of the fibula, associated with an almost transverse fracture of

the tibia, just above the base of the inner malleolus. In this form the lower end of the shaft of the tibia projects beneath the skin, and is likely to be mistaken for the tip of the malleolus; if this error is committed, and the fracture allowed to unite without proper rectification, considerable deformity results (Fig. 345).

(*d*) A similar injury in children and young people may produce a separation of the lower epiphysis of the tibia, whilst the fibula yields at a higher level. The line of separation in the tibia is more or less transverse, but may extend into the diaphysis on the outer side.

(*e*) Finally, in not a few cases wedge-shaped *marginal* chips may be broken off the anterior or posterior edges of the articular surface of the tibia, according to the direction of the violence.

In almost all of these varieties the ankle-joint itself is involved, and this, combined with the amount of bleeding that occurs into tendon sheaths and muscles around, and the difficulties sometimes experienced in complete reduction, explains why the results are frequently so unsatisfactory. Sometimes after union has occurred pain and deformity become increased owing to the patient being allowed to walk too early, the result being that the callus yields to the weight of the body. Should union occur with the foot in a false, *i.e.* everted, position, a large mass of callus develops between the shaft of the tibia and the malleolar fragment (Fig. 345).

FIG. 345.—MALUNITED SUPRA-MALLEOLAR FRACTURE, SHOWING CHARACTERISTIC ABDUCTION AND EVERSION.

2. **Displacement of the Foot inwards.**—When the patient slips on the outer aspect of the foot, the astragalus is forcibly driven against the inner malleolus, which may be broken off or impacted into it. The outer malleolus is dragged inwards with the foot, and owing to the integrity of the inferior tibio-fibular ligament, which acts as a fulcrum, the fibula yields at the same spot as in Pott's fracture. The foot is displaced inwards, and perhaps slightly backwards.

3. **Displacement of the Foot backwards,** by catching the heel and tripping forwards, is usually associated with fractures of the tibia and fibula through or just above the malleoli, but eversion of the foot is absent.

It is essential in all injuries of the ankle to have a thorough radiographic examination, which should be both antero-posterior and lateral. The importance of this is evident from the fact that many an oblique

fracture of the internal malleolus is scarcely visible in an antero-posterior radiograph, although very evident displacement is really present. It is also most desirable that the limb should be again radiographed after reduction and fixation, as it is extremely easy for some recurrence of the displacement to take place during the application of the retentive dressing.

Treatment.—The surgeon cannot exercise too much care in the reduction of the deformity caused by these fractures. The following points must be carefully noted: (*a*) The foot must be at right angles to the leg, and with this object in view treatment must be conducted, at any rate for a time, with the knee bent so as to relax the tendo Achillis. (*b*) The heel must not project unduly backwards, thereby indicating that reduction has not been perfectly accomplished. The articular surface of the astragalus should be within the grasp of the tibio-fibular mortice, and there must be neither anterior nor posterior projection if movements are to be subsequently free. (*c*) Lateral displacement and torsion must also be corrected, and apart from radiography this is secured when the inner surface of the great toe, the internal malleolus, and the inner edge of the patella are in the same plane. It is well, however, to compare the foot with its fellow, and in every case to have the limb radiographed after reduction.

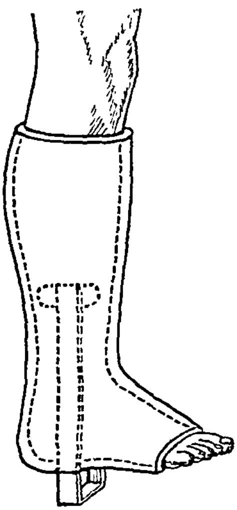


FIG. 346.—PLASTER AND METAL STIRRUP AMBULATORY SPLINT.

In reducing these fractures, therefore, the knee must be flexed and counter-extension made therefrom; traction is then exercised upon the foot to overcome both the antero-posterior, the lateral, and the rotary displacements. Manipulation will determine that a broken internal malleolus is in apposition with the shaft, and that the anterior edge of the tibia does not project unduly over the articular surface of the astragalus.

Reduction having been obtained, fixation is best secured by means of a plaster-cast extending from the tip of the toes to a point just below the knee-joint. The foot should be at right angles to the tibia, and the os calcis slightly inverted, the fore-part of the foot 'square' with the ground, as in walking (Fig. 346).

Massage and movements are usually unnecessary until after the fracture has united, if ambulatory treatment be adopted. A walking iron should be fitted and the patient told to walk, without crutches, after two or three days. The period required for union is about ten weeks. When the cast is removed it is wise to substitute a firm bandage of crêpe or elastoplast to limit œdema.

In cases where the displacement cannot be maintained by the plaster, continuous traction should be exerted for several weeks with the limb supported on a Braun's splint with a posterior supporting plaster cast, and by means of a Steinmann's pin passed through the os calcis.

Operative treatment is quite justified in cases where it is impossible to reduce the fragments by manipulation under a general anæsthetic. The replacement of the astragalus in a complete tibio-fibular mortice is so important that surgeons should not hesitate, when asepsis can be assured and the necessary manipulative skill is available, to cut down on and fix by plates or screws the separated fragments. A short plate on the fibula reaching above and below the line of fracture has a wonderful steadying effect upon the parts, especially if one of the screws be of sufficient length to traverse the fibula completely and penetrate the tibia; it can be easily removed under a local anæsthetic at a later date when it has done its work.

In cases of vicious union after Pott's fracture, it is usually necessary to redivide the fibula, and to excise a V-shaped portion of the tibia, perhaps extending into the ankle-joint, so as to enable the malleolus to be brought into contact with the shaft. The lower fragment must be fixed to the upper by a plate, screw, or peg.

Attention has already been drawn (p. 627) to a serious sequela of the fractures induced by abduction and eversion (and these probably constitute 90 per cent. of the whole), *viz.* the development of flat-foot. Naturally it results from an unremedied displacement; but even when reduction has been effectively secured and the bones have healed in good position, it may occur if walking is permitted too early, or especially if the arch of the foot is not sufficiently supported, and the weight deflected to the outer side by increasing the thickness of the sole of the boot on the inner, whilst the use of a walking-caliper is another necessary precaution.

Fracture of the Os Calcis is a common complication of falls on the feet from any but a very small height. The bone consists of a shell of compact bone which splits longitudinally when subjected to excessive strain, the lateral portion and the sustentaculum tali together with the medial portion of the posterior articular surface being separated from the central portion. Occasionally the anterior part of the bone is crushed, and on other occasions the lower and posterior part of the bone may be fissured. Associated with muscular action the so-called 'beak' fracture or separation of the posterior part of the tuberosity just above the insertion of the tendo Achillis results. The fracture is recognized by the pain over the bone, the bruising on the plantar surface, and the broadening in this region. X-rays will reveal the extensive fissuring and comminution that is present (Fig. 347), and it seems small wonder that the ultimate result of treatment of these fractures is often eminently unsatisfactory and accompanied by some such subsequent pain that subastragaloid arthrodesis is sometimes required.

Treatment.—Where there is little displacement or simple fissuring of the bone all that is required is to put the limb up in plaster, which may be fitted with a walking-iron, and maintaining this for some eight weeks or so. In treating the 'beak' fracture the displaced fragment can easily be replaced if the foot is held in a position of partial plantar flexion, which position is maintained during the period of immobilization. In all other cases an attempt must be made to restore the bone

to its normal shape. This is effected by exerting traction through a pin passed through the os calcis of some fifteen pounds' strength, and while this is maintained squeezing the lateral walls of the os calcis together either manually or with a clamp. This traction, exerted whilst the leg is placed on a Böhler's traction apparatus, reduces the vertical squashing of the bone and restores the angle which the anterior part of the superior surface makes with the posterior to approximately normal. Any antero-posterior shortening of the bone is corrected by traction exerted, not in the long axis, but at an angle of 45 degrees to this posteriorly. One of two procedures may then be adopted. Either the limb may be set up in a Braun's splint with continuous traction for some three months, or else while traction is maintained

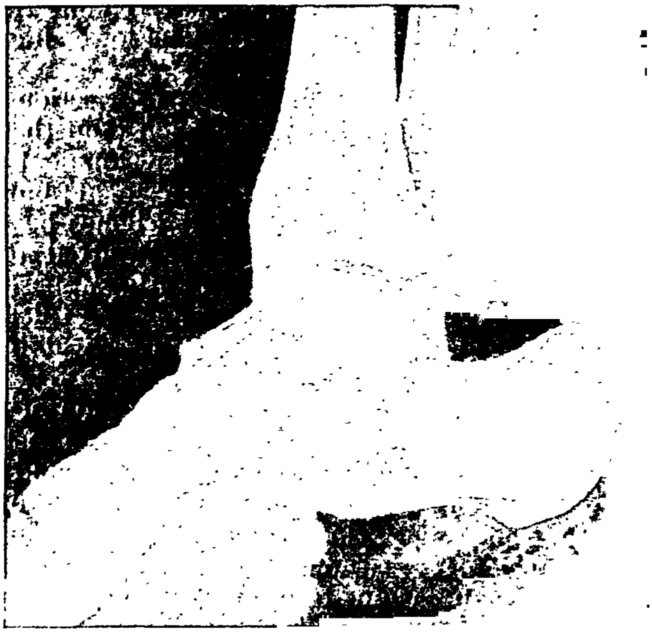


FIG. 347.—FRACTURED OS CALCIS.

a pin is passed through the lower end of the tibia, and this and that through the os calcis are incorporated in the plaster, thus preventing a recurrence of the displacement when the traction is withdrawn. A walking-iron may then be fitted and the patient allowed to get about in this. It should be maintained for some three months.

Fractures of the Astragalus may result from direct injury or from falls on the feet, and may affect the body or neck of the bone. If there is much comminution and collapse of the body, traction by a pin through the os calcis should be exerted for some six weeks, a walking-plaster then be substituted for a further similar period. Often, however, a fixed ankle will result. In fractures through the neck, the fractured surface of the proximal portion is rotated downwards, and

so strong traction with the foot in plantar flexion is necessary to impact the fractured ends, the limb then being put up in plaster in slight plantar flexion.

Fractures of the Metatarsals usually result from direct injury, but occasionally may occur as a result of prolonged marching over uneven roads (march fracture). Where no displacement exists, the leg and foot should be put up in a walking-plaster for some five or six weeks. In cases of displacement a wire frame with traction similar to that used for fractured fingers should be employed.

CHAPTER XXI.

DISEASES OF BONE.

General Considerations.—Bones are divided into the long, the short, and the flat, each of these consisting of compact and cancellous tissue. In the short bones there is but a thin layer of compact tissue surrounding a cancellous central mass, the meshes of which are filled with medullary fat and connective tissue. In the flat bones the compact tissue forms two limiting plates, separated by a layer of cancellous tissue (known in the skull as the diploë). In long bones the shaft consists of a tube of compact structure, surrounding a space which is normally filled with medulla, and known as the medullary canal; at each end it gradually merges into a larger mass of loose cancellous tissue, the interstices of which are similarly packed with vascular fatty medulla, which apparently performs the function not only of maintaining the nutrition of the bone, but also of elaborating the blood. Prolongations from the medulla extend into the Haversian canals, and are thence continuous with the periosteum, so that the mineral skeleton has incorporated within it a vascular fibro-cellular mass which permeates the whole structure.

The *vascular supply* of a bone is derived (*a*) from the nutrient artery which passes into the medullary space, and there breaks up into branches which ramify through the whole of the medullary tissue, and thence extend into the Haversian canals; and (*b*) from the periosteum, an exceedingly vascular ensheathing membrane, from which small vessels pass perpendicularly into the Haversian canals, and establish a communication between the two systems. These latter vessels are especially numerous and large close to the epiphyses. Large veins occur in the medullary and cancellous interior, and are frequently thrombosed in inflammatory mischief; if the thrombus becomes infected, and so disintegrated, pyæmia is very likely to ensue.

The *growth* of bone manifests itself in three different directions: (i.) It increases in length from the shaft side of the epiphyseal cartilage (or metaphysis), the epiphysis itself growing but little. In the upper limb the chief increase in length occurs at the shoulder and wrist, whilst in the leg it is mainly evident on either side of the knee-joint, and this in spite of the fact that the so-called nutrient arteries are directed away from these points. (ii.) Increase in breadth is produced by new formation under the periosteum. (iii.) A bone increases in density by a new deposit of osseous tissue around the Haversian canals and cancellous spaces.

Finally, it must be pointed out that the development and growth of the skeleton are largely dependent on the healthy activity of the

ductless glands; the pituitary and thyroid bodies certainly have considerable influence, and it is possible that the suprarenal, pineal, and thymus bodies are also not without effect. Enlargement of the parathyroid glands due to over-activity results in generalized osteitis fibrosa, a disease which may be arrested by the removal of the enlarged parathyroid. Moreover, efficiency of the food-supply and the presence of sunlight or its equivalent, together with the provision of certain mineral salts, are necessary if healthy bone is to be laid down or maintained.

Inflammation of Bone.

Much needless confusion has arisen in connection with this subject owing to the undoubted difficulty of understanding the pathological phenomena, but also largely due to careless and contradictory nomenclature. The following considerations may assist in making the subject more clear:

1. All inflammatory affections of bony tissue might rightly be termed **osteitis**, but when the medullary cavity of a long bone is particularly affected the term **osteomyelitis** is substituted, as also sometimes when masses of cancellous tissue, as in the os calcis, or sheets of it, as in the diploë, become the seat of acute inflammation. The term **periostitis** applies to the ensheathing membrane; the vascular connection between it and the underlying bone explains why inflammation of this structure is always associated with a superficial or deep osteitis, and why in an acute infective inflammation of the medulla of a long bone the periosteum is also liable to be affected.

Epiphysitis is the term applied to inflammatory affections of an epiphysis, which it must always be remembered has a vascular supply distinct from that of the diaphysis. As will be explained later, acute pyococcal affections do not often commence in the epiphysis, although it may be involved secondarily in an inflammation commencing in the neighbouring shaft; chronic diseases, *e.g.* tubercle and syphilis, do, however, involve epiphyses more frequently, though they are not limited to them.

2. In all inflammatory affections of bone the vascular structures are primarily involved, *i.e.* the medulla and its prolongations; the mineral element is only affected secondarily. The resulting phenomena, *viz.* hyperæmia, exudation, and tissue change, differ in no wise from those seen elsewhere, save that the effects are modified by the limited space in which the vessels lie, and the resisting character of the surrounding bony tissue. Hence any *acute* inflammation involving compact bone, associated with vascular engorgement and rapid exudation, leads to *necrosis* from thrombosis, due to increased pressure within the unyielding bony canals. If, however, the bone involved is cancellous, or the process *subacute*, so that the tissue-liquefying properties of the exudation and the tissue-absorbing activity of the leucocytes can come into play, then *osteoporosis* or *rarefaction* of the bone follows, a condition sometimes termed *caries*. Not unfrequently, however, some of the more resistant fragments of the bony cancelli escape absorption and die *en bloc*, constituting a condition of *cario-necrosis*. On the

other hand, if the inflammation is *chronic*, and due to causes other than tubercle or the pressure of tumours, then new formation occurs, and *osteosclerosis*, or condensation, is most likely to result. Tubercle in bones, as elsewhere, causes primary rarefaction of the tissue attacked, though sclerosis may be associated with or follow it.

3. It must always be remembered that necrosis, caries, and sclerosis of bone are **results** of inflammation, and not pathological processes or distinct disease. Each of them may arise from many distinct causes. Thus **Necrosis** results from the following conditions: (*a*) From acute localized suppurative periostitis, the sequestrum or dead mass being then simply a superficial plate or flake of the compact exterior (Fig. 348), the process by which it is cast off being described as 'exfoliation'; (*b*) from acute infective osteomyelitis, the sequestrum often involving the whole thickness of the bone, and invading more or less of the length of the diaphysis, if the condition is not early and efficiently treated (Figs. 352 and 355); (*c*) from acute or subacute infective osteitis of cancellous bone, the sequestra being small spiculated fragments of the bony cancelli which have escaped absorption; (*d*) from tuberculous disease of cancellous tissue, the sequestrum being light and porous, often infiltrated with curdy material, and rarely separated completely from surrounding parts (Fig. 364); (*e*) from syphilitic disease of cancellous or compact tissue, usually resulting from excessive sclerosis, or gummatous disease of the periosteum which has become septic (Fig. 366); (*f*) from the action of local irritants, *e.g.* mercury or phosphorus fumes gaining access to the interior of the teeth; (*g*) occasionally as a simple senile loss of nutrition, as in senile gangrene; and (*h*) a variety described by Sir James Paget under the name of 'quiet necrosis,' occurs as a result of direct injury, the sequestrum separating without suppuration; it is one of the causes of loose bodies in joints, and especially the knee, following a blow on one of the condyles.

The presence of dead bone in a limb may be suspected when one or more sinuses are present, discharging pus or serum according to circumstances, with puffy granulations, pouting round the opening, and the underlying bone thick and enlarged. A probe passed down the sinus can usually be made to strike against the sequestrum, perhaps after passing through a casing of new bone, and its fixity or freedom may be demonstrated in this manner.

Caries, or, as it is sometimes called, *osteoporosis* or *rarefaction of bone*, is characterized by a soft and spongy state of the bone, which, if it can be reached, readily breaks down on pressure with a probe. It may result from the following conditions: (*a*) from acute or subacute infective inflammation of cancellous tissue; (*b*) from tuberculous affections of the cancellous tissue or periosteum; (*c*) from syphilitic disease of the medulla or of the under surface of the periosteum. The spongy vascular condition of the bone ends during the early stages of repair of a fracture is practically identical with this condition.

Pathologically, it is characterized by the replacement of the medulla by granulation tissue, which usually contains some large multinucleated cells, or *osteoclasts*, and these seem to be closely connected with the removal of the bone. The cancellous tissue becomes hollowed

out to accommodate these granulations, and the osteoclasts are usually found occupying shallow depressions known as 'Howship's lacunæ.' In tuberculous and syphilitic lesions the bone corpuscles often undergo fatty degeneration.

Caries may occur with or without suppuration (*C. sicca* or *suppurativa*); sometimes the development of granulation tissue is excessive, as when it fungates into a joint (*C. fungosa*). Not unfrequently it is associated with necrosis, constituting a condition of *cario-necrosis* (or *C. necrotica*), as in infective inflammation of cancellous bone, minute spiculated sequestra being found in the discharge, whilst in tuberculous osteitis sequestra of larger size often occur. In fact, caries and necrosis bear much the same relation to one another as ulceration and gangrene of the soft tissues.

If caries is recovered from, a condition of sclerosis usually follows, sometimes with loss of substance and deformity.

Sclerosis of bone (osteosclerosis) is invariably the result of some chronic inflammatory affection, *e.g.* (*a*) chronic periostitis, whether simple or syphilitic; (*b*) chronic osteomyelitis, simple, tuberculous, or syphilitic; or (*c*) chronic osteitis of the compact bone, which is always secondary to one of the former. In all cases the condition is due to a slow formation of new bone within the Haversian canals or cancellous spaces, thus diminishing their lumen; in syphilis this may progress to such an extent as to lead to their total occlusion, and even to localized necrosis from lack of blood-supply, especially when sepsis gas occurred. In tuberculous bones the sclerosed tissue is always at some distance from the focus of mischief, and may be looked on as Nature's attempt to limit the spread of the disease; it forms also the final tissue or bone-scar in the process of repair when a cure has been obtained by natural or surgical means.

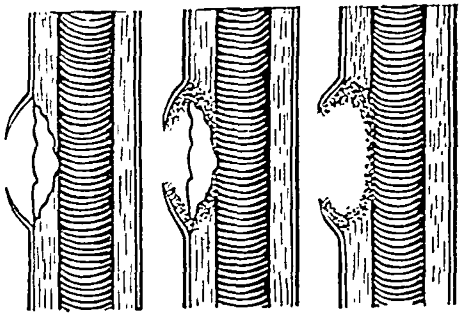
Acute Inflammation of Bone.

1. **Acute Localized Periostitis** usually arises as a result of traumatism applied directly to the bone, with or without an open wound; it may also be determined by an extension of inflammatory mischief, as in an alveolar abcesss.

Pathologically, the process consists of hyperæmia and of exudation into the periosteum, which becomes swollen, turgid, and thickened. This may be followed in due course by resolution, or may leave the bone thickened and in a condition of chronic inflammation; or suppuration may ensue, and with it usually a limited superficial necrosis. In the last event pyogenic organisms of no great virulence find an entrance to the area of mischief, and probably in cases due to trauma through the abraded or injured skin; in other instances they may come from neighbouring foci of inflammation, or from the blood. The inflammatory process extends to the small vessels entering the bone from the under surface of the periosteum; these become dilated, thrombosed and strangled by the pressure of the exudation around them, and finally pulled out from the osseous canals by the tension of the subperiosteal effusion. Consequently, the vitality of the superficial layer of bone is impaired, if not destroyed, for an area corre-

sponding almost exactly to that from which the periosteum has been stripped (Fig. 348, A).

As soon as tension has been relieved by the escape of the pus, repair commences. Where the mischief is slight and superficial, the involved bone may entirely recover, necrotic portions being absorbed, if the surrounding parts are sufficiently vascular. If the dead portion of bone is compact and more extensive, it will be separated from the subjacent living tissues by one of the processes already described, whilst on the under surface of the stripped-up periosteum a casing of new bone develops, constituting an *involucrum* or sheath, at first spongy and cancellous in texture, but finally hard and sclerosed. In the centre of this new formation are found one or more openings or *cloacæ* through which the discharge escapes, and corresponding in position to the apertures in the periosteum and skin made for the exit of the pus (Fig. 348, B).



A B C

FIG. 348.—SUPERFICIAL NECROSIS RESULTING FROM A LOCALIZED PERIOSTITIS (DIAGRAMMATIC).

A represents the necrosed tissue lying in continuity with the surrounding living bone; the periosteum is stripped up from it, and has an opening through which the pus has been discharged. B shows a later stage in which the sequestrum is being separated by a process of rarefying osteitis in the immediately contiguous living bone, whilst an involucrum, or sheath of new bone, is formed from the under surface of the periosteum; a cloacal aperture remains in the involucrum for the escape of discharges. C shows the condition of affairs after the sequestrum has been removed.

Clinically, the symptoms of acute localized periostitis consist in the ordinary phenomena of acute inflammation, the pain being of an intense aching character, worse at night, and increased by lowering the limb or by any kind of pressure. If a subcutaneous portion of bone is involved, a painful swelling develops, at first brawny in character, but when suppuration has occurred the centre softens, whilst the skin over it becomes red and œdematous. When an abscess has burst or been opened, bare bone is felt beneath the periosteum, and the greater part of this denuded structure usually dies, and must then be either absorbed or separated; in either case a sinus remains for a time, leading down through a cloaca in the involucrum to the sequestral cavity. From this either pus or serum will be discharged, according to whether a mixed infection of the wound has occurred or not. The time required for the separation of a portion of dead bone varies with its size and density, and with the vascularity of the surrounding parts; thus it may take over three months for a sequestrum to be set free from the shaft of the femur, whereas a period of five or six weeks will suffice if the ulna or radius is involved. That the sequestrum is free may be ascertained by

moving it with a probe within the osseous cavity, or perhaps more surely by radiography.

Treatment.—Rest, elevation of the limb, and fomentations are usually relied on locally in the early stages, and favourable reports have been given as to the value of Bier's induced hyperæmia. If, however, the affection is not readily checked, and suppuration threatens or develops, a free aseptic incision down to the bone is the best means of preventing or limiting necrosis. When necrosis has occurred, the parts must be carefully dressed and kept aseptic until the sequestrum is absorbed or set loose. In the latter case an incision is made over the involucrum, the periosteum stripped from it, one of the cloacæ enlarged, and the dead bone removed. The cavity will then rapidly fill up and heal by granulation.

2. **Acute Infective Osteomyelitis** (*syn.:* **Acute Necrosis, Acute Diffuse or Infective Periostitis, Acute Diaphysitis, Acute Panostitis**).—This disease usually occurs in children, and in boys more often than in girls (6 : 1), and not unfrequently follows one of the exanthemata, *e.g.* measles or scarlet fever. It generally commences before the age of puberty, and is an affection of the gravest import; the multiplicity of names attached to it suggests quite accurately that its manifestations may be very diverse in character.

Pathology.—The patients are always in an unhealthy condition, with low germicidal powers, and may present one or many foci of local suppuration, *e.g.* diseased teeth, or ulcerated gums or throats, impetigo, otitis media, or the evidence of lesions in the gastric or intestinal mucous membranes. An infected condition of the blood is almost always present before the attack. The causative organisms are usually *staphylococci* (78 per cent.), but *pneumococci* were found in 14 per cent., and *streptococci* in 6 per cent.; these figures refer to 400 consecutive cases.

A slight injury in the shape of a strain or a wrench, which is often entirely overlooked, may suffice to determine a small hæmatoma which provides a suitable nidus for any organisms circulating in the blood-stream. Moreover, the fact that the vessels on the metaphyseal side of the epiphysis are end-arteries is a further determining factor in the hold-up of any circulating emboli. The majority of the ligaments and not a few tendons are inserted into the epiphysis, and hence articular strain must be mainly felt in the juxta-epiphyseal region, *e.g.* immediately beyond these insertions. It has been already mentioned that the traumatic separation of epiphyses is liable to be followed by suppuration, even in healthy children, and it is easy to understand that in an unhealthy child a very slight injury in the epiphyseal region may determine a similar process.

The disease almost always starts in the soft vascular tissue of the metaphysis (p. 640), but in a few instances (mainly amongst young adults) it may be preceded by a patch of localized periostitis, suggesting that an acute infection has supervened upon a subacute periosteal focus. The nature and extent of the inflammatory phenomena depend largely ont he exact situation of the infective focus, the amount of resistance offered by surrounding tissues, and the virulence of the

organisms. As in any other part of the body, the trouble is most likely to travel along the line of least resistance.

(1) If the process commences in the periphery of the juxta-epiphyseal region close to the periosteum, the line of least resistance will be towards that structure, and hence a *subperiosteal abscess* may form, whilst the central portions of the bone may escape almost entirely (Fig. 349). The size of this abscess varies, but considerable portions of the diaphysis may be denuded, resulting in extensive necrosis. It rarely spreads to the neighbouring joint, owing to the close bond of union which exists between the diaphyseal periosteum and the epiphyseal cartilage. In this form an early incision to let out the pus may suffice to prevent necrosis, or, at any rate, to limit it. The constitutional symptoms will be less severe than in other varieties; there is less likelihood of the development of pyæmia, and the toxic fever soon disappears after the removal of the pus. Subsequently the same course of events occurs as in the localized variety of acute periostitis, *viz.* an involucrum forms, perforated by one or more cloacæ, and the sequestrum in time separates.

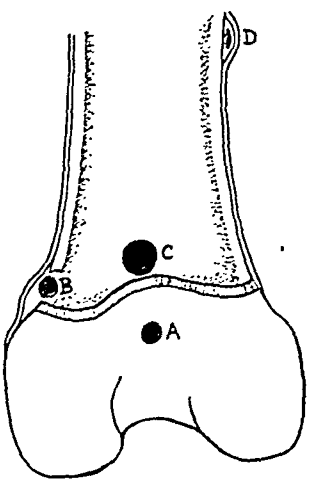


FIG. 349.—ORIGINAL FOCI OF OSTEOMYELITIS.

A, In epiphysis; B, under periosteum at end of diaphysis; C, in metaphysis the usual site; D, under periosteum along shaft.

A good illustration of this type is to be found in the acute periostitis which affects the *lower end of the femur*. It almost always starts posteriorly, stripping the thin periosteum off the back of the bone as far as the bifurcation of the linea aspera. Its preference for this situation is due to the fact that strains upon the knee-joint are mainly felt when the limb is hyper-extended, and that such strain is directed to the posterior ligaments, and hence the posterior portion of the epiphyseal line is likely to suffer. Suppuration follows, and if not recognized and treated early, may burst through the thin periosteum and be widely diffused under the quadriceps. The involucrum in this affection is often defective behind.

(2) Should the process start in the centre of the metaphysis, it may spread in several directions, and the results vary considerably.

(*a*) The process may reach the periosteum first, and then the phenomena of a diffuse subperiosteal abscess, as indicated above, with the addition of the symptoms due to its deeper origin, will manifest themselves. This is, perhaps, the most usual course for the disease to take.

(*b*) If the infection extends along the medullary cavity, the most typical form of osteomyelitis ensues (Fig. 350). The medulla becomes intensely hyperæmic; the veins are thrombosed; localized foci of suppuration and gangrene appear; and in consequence of the increased pressure infective emboli are likely to be detached and pyæmia

to follow. Even if the latter does not supervene, the general condition is profoundly affected by the absorption of toxins. Suppuration also occurs beneath the periosteum, although the amount of pus may not be great at first; but the membrane is stripped up from the diaphysis, perhaps to such an extent as to involve the whole length and circumference of the shaft. Unless prompt measures are taken to limit the progress of the disease, necrosis is certain to follow, usually implicating the whole thickness of the diaphysis, and sometimes its whole length; in fact, the diaphysis is occasionally found lying loose in an abscess cavity, the two epiphyses having been detached. A similar result is sometimes due to the trouble starting at each end of the

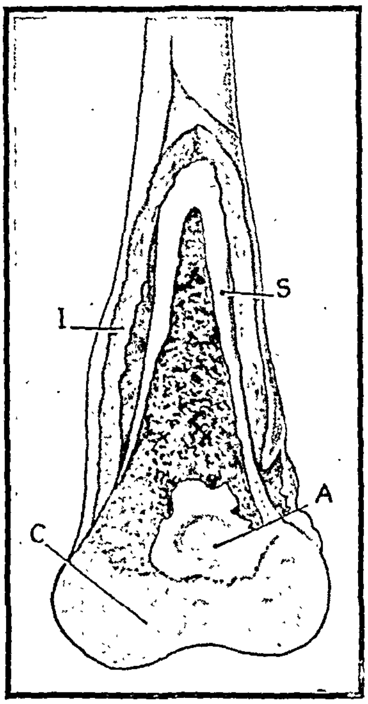


FIG. 350. — ACUTE OSTEOMYELITIS OF THE LOWER END OF THE FEMUR IN A CHILD OF NINE WEEKS.

A, Abscess cavity in lower end of diaphysis; S, sequestrum; I, involucrum; C, epiphysis.

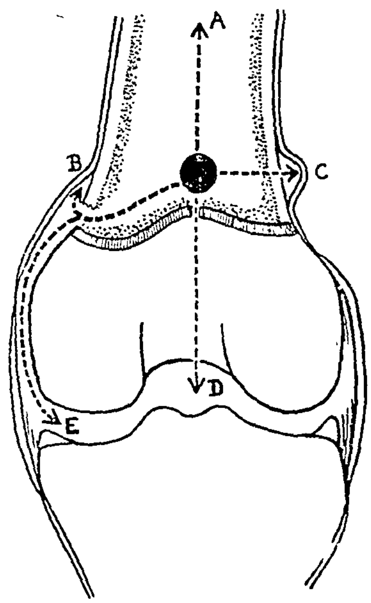


FIG. 351.—SPREAD OF OSTEOMYELITIS.

If the primary focus is in the metaphysis, spread may occur down the medulla (A), through the compact tissue near the diaphyseal cartilage under the periosteum (B), or into the joint (E), through the compact tissue of the diaphysis to form a subperiosteal abscess (C), or directly through the epiphysis into the joint (D).

diaphysis. As a rule the epiphysis, even though detached, retains its normal position; but sometimes it becomes displaced, and then deformity results.

(c) Owing to the intimate connection between the periosteum of the diaphysis and the epiphyseal cartilage, the neighbouring joint usually escapes infection, although it is often the site of a sterile synovial effusion. Should, however, the epiphyseal line be within the joint, as in the hip, it must perforce become the seat of an acute infective arthritis as soon as the bacteria reach its periphery. The elbow-joint is similarly liable to suffer when bacteria attack the

upper end of the ulna, since the epiphysis is a mere flake of bone, and the greater part of the olecranon is derived from the shaft. Sometimes the junction cartilage is softened and destroyed by the organisms, so that the inflammation spreads through the epiphysis to the articular cartilage, which is eroded, and the joint opened. Occasionally the pus burrows along the soft tissues outside the bone, as along the biceps groove into the shoulder-joint.

FIG. 352.—OSTEOMYELITIS OF THE TIBIA. (KING'S COLLEGE HOSPITAL MUSEUM.)

The sequestrum, composed of the eroded diaphysis, lies in a cavity surrounded by new bone, from which discharging sinuses open on to the skin. The knee-joint is distended with fluid.

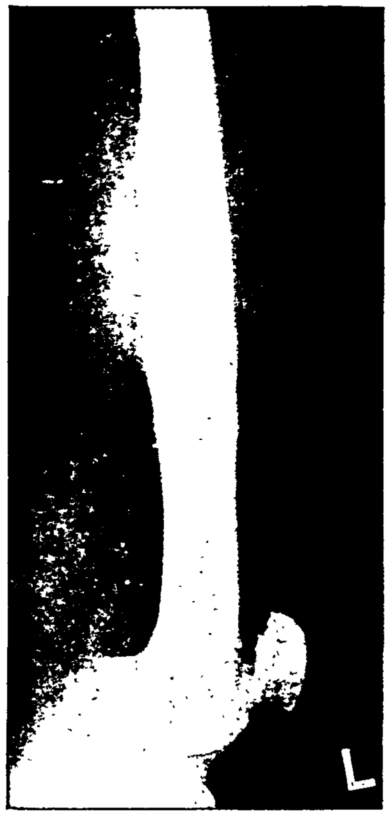


FIG. 353.—CHRONIC ABSCESS IN THE MIDDLE OF THE SHAFT OF THE FEMUR (BRODIE'S ABSCESS).

(*d*) When the organisms are of a less virulent type, the process may be much more localized and subacute in nature, resulting in a limited central necrosis, or in a chronic abscess inside the bone (*Brodie's abscess*) if the part involved consists of a mass of cancellous tissue, as in the head of the tibia. A similar condition may affect certain epiphyses which occur away from joints, and some chronic abscesses in such situations as the great

trochanter may be explained on these grounds. A chronic abscess of this nature may exist for many years, and cause much thickening of the surrounding bone from sclerosis (Figs. 353 and 354).

Another mild type is that known as **Albuminous or Serous Osteomyelitis.** It is usually seen in young children, and in not a few cases is due to the pneumococcus, but in others is caused by a staphylococcus of low virulence, *e.g.* the *St. pyogenes albus.* The local and general phenomena are both less severe in character, and often clear up without the onset of necrosis. The swelling is brawny and œdematous, and even if pus forms it is delayed and not accompanied by acute pain; neighbouring joints are likely to be distended with a serous exudation. The temperature does not run high, and there is but slight leucocytosis. Early operation does harm in these cases, which should be treated by rest and hot applications. If an abscess forms, it is opened and drained, and if necrosis occur no attempt must be made to remove the sequestrum until it has separated.

FIG. 354.—LOCALIZED ABSCESS IN THE LOWER END OF THE FEMUR EXTENDING FROM THE EPIPHYSEAL LINE UPWARDS INTO THE MEDULLA. (FROM SPECIMEN IN THE COLLEGE OF SURGEONS MUSEUM.)

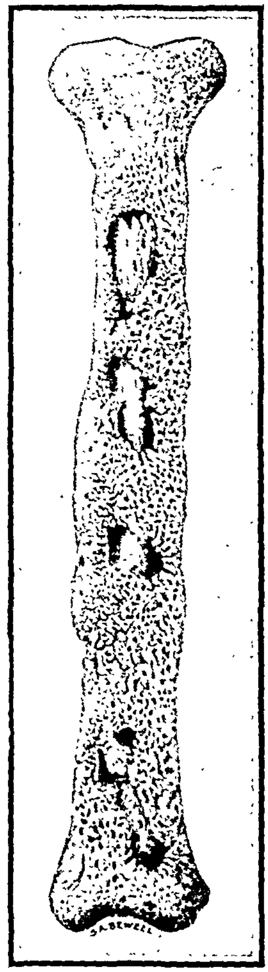


FIG. 355.—NECROSIS FOLLOWING ACUTE OSTEOMYELITIS. (FROM SPECIMEN IN COLLEGE OF SURGEONS MUSEUM.)

The irregular new bone of the involucrum is well seen, and within it portions of the sequestrum.

An occasional result of a subacute non-suppurative osteomyelitis

is bending of the affected bone, especially if the patient is able to put any pressure or weight on it.

(3) In the flat bones, such as the innominate, scapula, and those of the cranium, the cancellous tissue becomes filled with pus, and owing to the abundant supply of veins pyæmia is very likely to develop. Abscesses may form on both sides of the bone, and a large extent of necrosis may result. In the skull a subcranial abscess may develop, and possibly a true abscess in the brain.

Clinical History.—The disease usually commences abruptly with a rigor, followed by high fever and severe pain in the limb, which soon becomes swollen, brawny, and congested. It may be mistaken for an acute attack of rheumatism, although the fact that the interarticular portion is affected, and not the joint, should prevent this error. The pain is of an extremely severe nature, so that the child screams whenever the limb or even the bed is touched.

Should the trouble be mainly limited to the periosteum, evidences of its being stripped off the bone and of the accumulation of pus beneath it soon show themselves. An abscess forms which may quickly transgress its periosteal boundary and burrow under fascial or muscular planes; its limitation to the diaphysis has been already explained; but, although the neighbouring joints may escape infection, they are very likely to suffer from a serous exudation, and subsequently some restriction of movement may be observed. Sooner or later the abscess bursts or is opened, giving exit to a larger or smaller quantity of pus, and the subjacent bone is found bare and apparently dead. Possibly the relief of tension may suffice in some cases to limit the mischief, the periosteum again becoming adherent to the bone, and a cure being established without extensive necrosis. More frequently a considerable portion of the shaft loses its vitality and has to be separated in the manner already described, whilst an involucrum forms around it from the periosteum (Figs. 352 and 355). If a mixed infection has not occurred, no fever or bad constitutional symptoms need be expected during this later stage. Pathological fracture sometimes occurs as a complication if undue strain is placed on a limb which has been weakened by osteomyelitis.

When the medulla itself is more especially involved, the symptoms of pyæmia or of severe toxæmia become very prominent, and the child may die from this cause before the local mischief has been able to advance very considerably. The pain will continue to be of a severe character, although the patient's perceptions may be so blunted by the toxic condition that he becomes more or less unconscious. The swelling of the limb is not so great as in the former type, but the mischief may be very extensive, and although there is no great collection of pus beneath the periosteum, yet it may be stripped up along the whole length of the shaft, which may even be detached from the epiphysis at each end. Should the child not die of toxæmia, extensive destruction of bone is certain to result.

In infants and very young children, especially if the subjects of inherited syphilis, the disease early spreads through the non-vascular cartilage of the epiphysis to the neighbouring joint, and the symptoms

of acute suppurative arthritis supervene. The head of the humerus and the upper and lower ends of the femur are the parts most commonly involved in this way. In some of these cases the ligaments are so seriously weakened and relaxed that a loose flail-joint results, and pathological dislocation may result.

Differential Diagnosis.—Certain conditions may cause difficulty.

(1) *Acute Suppurative Arthritis.* Here the point of maximum tenderness is not placed over the bone but in the joint. The slightest movement of the joint, which is held in a position to give maximum room

FIG. 356.—KÖHLER'S DISEASE.
Note the marked increase in density and diminution in size of the scaphoid.

for the effusion, gives rise to much greater pain than in osteomyelitis. The effusion is usually greater than that accompanying osteomyelitis, and if in doubt aspiration will reveal its nature.

(2) *Acute Rheumatism.* Here more than one joint may be affected, and the pain and toxæmia are rarely as acute as in osteomyelitis. Signs in the heart aid the diagnosis.

(3) *Erythremia crurum puellinum frigida.* A condition in which bluish-red swellings are present, usually over the calves of young females, may sometimes cause difficulty. Multiplicity of the lesions is usually present and toxic signs are minimal.

(4) *Cellulitis.* The inflammation here is superficial and the thickening does not extend deeply. Passive movement of the joint causes little pain.

(5) *Ewing's Sarcoma of Bone* is often recognized only by the X-ray

appearance or by the material removed at operation, as up to this stage it resembles osteomyelitis so closely.

Schlatter's Disease is probably a low-grade subacute infection following on injury involving the upper end of the tibia in young people. It is probably due to a slight injury directed to the lower tongue-shaped prolongation of the upper epiphysis, which forms the tubercle of the tibia, and is followed by a subacute inflammation of the epiphyseal line, which does not result in suppuration. The child complains of a tender swelling in this region without any affection of the joint, and walks with a limp. Radiographic examination suggests displacement forwards of the epiphysis, but there is no mobility. Treatment consists in rest and protection of the part from injury, and in time the condition gets well.

Köhler's Disease is a similar affection limited to the scaphoid bone (tarsal), which is somewhat enlarged and sensitive to pressure. In the X-ray picture (Fig. 356) the bone or its ossified centre appears to be abnormally dense, shortened antero-posteriorly, and correspondingly broader. The condition usually appears in adolescents, and is likely to be mistaken for static flat-foot; it causes a limp. It may be due to injury, but the symptoms are transitory, and a return to a practically normal condition under the protection assured by a flat-foot support is the rule in a year or more.

FIG. 357.—SKIAGRAM OF A CASE OF KIENBÖCK'S DISEASE.

Kienböck's Disease also comes under this heading: it is a quiet sclerosing osteitis of the carpal semilunar, and the X-ray appearance is very similar to that of the tarsal scaphoid in Köhler's disease (Fig. 357). There can be no doubt that in a certain number of cases traumatism plays an important part, and it sometimes follows a typical crush fracture of the bone.

Apophysitis of the Os Calcis is a condition similar to Schlatter's disease. There is an epiphysis over the tuberosity of the os calcis, which commences to ossify between the seventh and ninth years, and fuses with the bone between the sixteenth and twentieth years. Slight injury may cause enlargement of the heel, which on X-ray examination may show apophysitis. The epiphysis may be fragmented, and the clear area between the epiphysis and the body of the os calcis may be broader than normal (Fig. 358). On each side of this area the bone is irregular, as if ossification had been interfered with. Treatment consists in rest of the part, and protection from further injury.

Freiberg's Disease.—This is an uncommon affection of the epiphysis of the head of the second metatarsal bone; it is probably an example

of *osteochondritis juvenilis*. The condition is probably caused by trauma, and as the second metatarsal is the longest, it is perhaps subject to more trauma than the other metatarsals. The X-ray picture is quite typical; the rounded head of the bone becomes flattened and quadrangular in shape. The symptoms are pain in the foot and tenderness over the head of the metatarsal.

With regard to treatment a metatarsal bar may give relief, but in most cases a cure can be effected only by excision of the enlarged metatarsal head.

FIG. 358.—APOPHYSITIS OF THE OS CALCIS.

This condition is analogous to Perthes' and Köhler's disease. Note the condensation and fragmentation of the calcaneal epiphysis, also the cloudiness and irregularity of the posterior border of the adjacent os calcis, which in some cases is much more marked.

The **Prognosis** of the acute form of osteomyelitis is always grave. Life may be threatened by pyæmia or toxæmia in the early stages, whilst later hectic fever, amyloid disease, and exhaustion may terminate the case if a mixed infection has occurred.

The utility of the limb may be unimpaired if the disease has not been too extensive, and if prompt treatment has been adopted; but if life is threatened by toxæmia, or if neighbouring joints suppurate, or if the osteogenetic powers of the periosteum have been destroyed by the acuteness of the process, amputation may be required.

Treatment.—Prompt surgical interference must be adopted in order, if possible, to cut short the malady. As soon as the local pain and high fever give evidence that this affection is present, a free incision should be made in the long axis of the limb through the periosteum, whether pus can be detected or not. The surgeon will then proceed to investigate carefully the condition of the bones by inspection and the use of the finger and probe. As a rule, he will find himself in the neighbourhood of the epiphyseal cartilage, and if the case has been taken in hand early it is possible that the mischief will be quite limited; all that is then required is to scrape or gouge away the softened and hyperæmic bone at the end of the diaphysis, together with any necrotic tissue which may be present, taking the greatest care not to perforate the epiphyseal cartilage. The cavity thus formed is drained or packed with gauze, infiltrated with bipp, and in all probability recovery will rapidly ensue.

If the case has gone further, the periosteum will be found stripped from the bone for a varying distance, although but little pus may be present beneath it. If pus is present, this is an indication that there is drainage from the medullary cavity, and all that is required is free incision of the periosteum and exposure of the abscess cavity to the surface to ensure escape of the pus.

When the periosteum is hyperæmic and swollen, yet no pus is present beneath it, then in these cases it is essential to open the medullary cavity to allow of free escape of the dammed-up pus. Until recently it was the custom to gouge away large areas of the shaft and form a gutter, exposing freely the medullary cavity. It is, however, difficult to determine to what extent the medullary cavity is infected, and it is very easy to open up non-infected areas and thus spread the infection. It is most desirable, therefore, to establish communications between the medullary cavity and the surface by drilling the bone with several drill holes, or trephining it with a conical trephine. The opening thus made is ample to allow of escape of pus and allay the toxæmia, and the boundaries of the necrosis will eventually demarcate themselves. This conservative operation has a far lower mortality than the more radical one. When grave constitutional phenomena are present, associated with loosening of the epiphysis, it may be necessary to amputate in order to prevent death from toxæmia.

If the periosteum has been extensively involved, a large amount of bone, possibly the whole diaphysis, is denuded, and perhaps both epiphyses are loosened. The dead diaphysis should be removed at once if the leg or forearm is involved, as there is always a second bone to maintain the length of the limb; but for the femur and humerus its removal should be delayed—immediate removal would lead to hopeless shortening and crippling.

At the termination of this operation the best treatment is to pack the wound with gauze soaked in sterile vaseline, perhaps putting a suture or two in the ends of the incision, and then to encase the limb in plaster of Paris. A window may be cut over the wound, but the dressings should not be disturbed unless some indication, such as a rise in temperature, points to their replacement, for several weeks. At

the end of this time, although the wound smells foul, under the dressings will be found healthy granulations. The procedure is then repeated. Other methods of treatment whereby the wound is repeatedly dressed or continuously irrigated with Carrel-Dakin solution are not so satisfactory.

When the sequestrum is free—that is, in about two or three months—*sequestrectomy* will be required; it consists in reflecting the periosteum from the new casing, and in enlarging or uniting one or more of the cloacæ, so as to allow the sequestrum to be withdrawn. In some cases it is desirable to approach the sequestral cavity by some safer route than that suggested by the sinus; *e.g.* when the necrosis involves the lower end of the femur, it is often wise to cut down on it from the outer side, although the sinuses are central. It is not always easy to remove the sequestrum *en bloc*, and it may be necessary to divide it; the greatest care must be taken not to leave any portion behind, as the wound cannot heal in this case. The empty cavity should be dealt with by one of the methods detailed below, or alternatively the method described in the treatment of the acute case can be adopted. Occasionally removal of the sequestrum is almost impracticable, and under such circumstances *amputation* may be preferable. This summary proceeding may also be needed in the course of this disease on account of pyæmia, defective repair, exhaustion from chronic toxæmia, or suppuration in a neighbouring joint.

Osteomyelitis of the flat bones involves opening freely into the cancellous tissue by gouge or trephine, and scraping away all the bone which is diseased or infiltrated with pus. In the cranium the inner table should not be perforated unless the surgeon suspects the existence of subcranial suppuration.

The **closure of a cavity left by the removal of a sequestrum** (or of a growth from the interior of a bone or of a tuberculous focus) is not always simple, inasmuch as the walls consist of osseous tissue which is not too well supplied with blood, and which becomes less vascular as the condition becomes more chronic. The shape of the cavity also influences the rapidity of the healing process.

The ideal cavity to leave after the removal of a sequestrum is a shallow crater, over the margins of which the soft tissues can be adapted. After removal of the sequestrum and of that portion of the involucrum which overhangs the cavity, bleeding is checked by the use of swabs wrung out of hot saline; the cavity is then mopped over with absolute alcohol or ether, carefully 'bipped,' and then the soft tissues are drawn together over the hollow so as to close it entirely, or the wound is packed with 'bipped' gauze, which may usually be left *in situ* for ten days. In some cases it may be possible to detach one or both bony sides of the cavity and press them inwards so as to reduce its size. Bone grafts have also been utilized, *e.g.* a phalanx clipped up into small fragments, and fat grafts, but the best method of filling up such a cavity is by means of a pedunculated muscle graft turned in from the neighbourhood, *e.g.* from the gastrocnemius or soleus for cavities in the tibia.

Sinuses penetrating through the whole thickness of a bone are

most difficult to heal, inasmuch as the bony walls cannot fall together. In such cases the total removal of one side of the tunnel may suffice to permit the soft tissues to fall in and close up the space; but if this is not possible, then the cavity must be cleared and cleansed, and some grafting process (bone or muscle) adopted.

At all stages of the disease thought must be given to the possibility of such complications as embolic infection of other bones, empyema, pericarditis, brain abscess, and infective arthritis, all of which must be treated as they arise.

3. The **Acute Traumatic Osteomyelitis** which arises as a result of infection from without, *e.g.* in cases of compound fractures, and after amputation, excision, or even osteotomy, requires a separate description. The clinical history of a case involving the shaft of a long bone is as follows: The patient during an attack of septic traumatic fever due to an injury or operation has one or more rigors, which suggest the existence of pyæmia, and is suddenly seized with severe pain in the limb, which becomes intensely sensitive. On examining the wound, the soft parts are found to be unhealthy and infiltrated, the lower end of the bone is bare and yellow, and from the interior a stinking mass of gangrenous medullary tissue sometimes protrudes. Should early and efficient treatment not be undertaken, the patient runs a considerable risk of succumbing to acute pyæmia or toxæmia, whilst a varying amount of the interior of the bone dies (*central or tubular necrosis*), and a small segment of its whole thickness below, so that the sequestrum which ultimately separates is annular and conical (Fig. 359). Should the patient survive, the necrotic tissue gradually separates, and during this process a mass of new bone is formed from the under surface of the periosteum, so that the shaft becomes much thickened externally.

FIG. 359.—TUBULAR OR CONICAL SEQUESTRUM FROM ACUTE OSTEOMYELITIS OF FEMUR AFTER AMPUTATION.

Treatment.—The wound is thoroughly opened up as early as possible, flushed out, and the sloughing medullary tissue scraped from the interior of the bone, which is subsequently disinfected with pure carbolic acid, a drainage wick of gauze or rubber glove being placed in it for a few days. A certain amount of necrosis follows, but without high fever or toxæmia. Should this treatment fail, amputation will be required, or complete excision of the affected segment of bone.

4. **Acute Osteomyelitis of Cancellous Tissue** develops after an infected wound of the short bones, or of the cancellous extremities of long bones; it may also be caused primarily by auto-infection, or may be secondary to acute infective arthritis, or the result of a pyæmic embolus. The local and general phenomena are very similar to those detailed above, except that no large sequestra are formed, the dead bone coming away in spicules (one form of

caries necrotica), whilst the pain and fever are less severe, and there is less likelihood of the development of pyæmia. *Treatment* consists in opening up the infected area and removing all diseased tissue; the cavity thus formed must be efficiently drained, if need be through a counter-opening, and may advisably be packed with 'bipped' gauze. The general health must be attended to, and care taken to prevent or limit deformity.

5. **Typhoid Osteitis.**—Affections of the osseous system are not uncommon in typhoid fever, and usually come on during the early stages of convalescence. The tibia and ribs are most often affected, and in a large percentage of cases typhoid bacilli, with or without pyogenic cocci, will be found. The trouble commences either as a periostitis or osteomyelitis, subacute in character, often improving temporarily, and then relapsing; it is curious to note how long the organisms may lie latent in the tissues before causing an abscess. In time an abscess usually develops, together with some amount of necrosis or caries. Sometimes an abscess within the bone communicates through a small sinus with one beneath the periosteum, constituting the so-called 'collar-stud' abscess. On its first appearance the affected limb should be elevated and fomented, and frequently the more acute symptoms will yield; but the part often remains enlarged, swollen, and tender, and exacerbations of pain are not unlikely to develop from time to time, culminating sooner or later in abscess formation. When suppuration has occurred, the parts must be freely incised, diseased bone removed, granulation tissue scraped away, and the parts disinfected with 'bipp.' The wounds are usually found to be extremely chronic and indolent, and may require scraping several times.

Acute Epiphysitis is a condition occurring in young children and accompanied almost invariably by a fatal issue. It is an acute infection of the epiphysis, usually by the streptococcus, which gains entry through the circulus vasculosus of Hunter, an anastomosis of vessels around the synovial reflection on to the bone. The child is acutely ill, often moribund, from toxæmia. There is a large effusion into the joint, which by aspiration can be shown to be teeming with organisms.

Treatment consists in draining the joint, but where the toxæmia is advanced amputation is probably the best treatment.

Chronic Inflammation of Bone.

Chronic Osteo-periostitis is a chronic inflammatory condition of the bone, which results in overgrowth, thickening, and condensation.

Varieties.—(*a*) It may arise as a *localized* chronic periostitis, traumatic, toxic, rheumatic, or syphilitic in origin, or due to the close proximity of a chronic ulcer. It is characterized by a formation of new bone beneath the periosteum, the so-called *node* (Fig. 360), the cancelli of which are arranged at right angles to the surface. At first this new material is soft and spongy, but it rapidly becomes hard and sclerosed, and a similar condition affects the subjacent compact structure, which is thickened and indurated by a new formation

around the Haversian canals. If the irritation persists, as in the case of a chronic ulcer, this condition may run on into the following variety.

(*b*) The *diffuse* form of chronic osteo-periostitis usually originates in some deep-seated or central affection, tuberculous or syphilitic in nature, and often involves the whole bone, although sometimes limited to one or other end. If tuberculous, there may be a small chronic abscess or some central necrosis, and around this the bone becomes thick and indurated. In the later stages a considerable new formation may occur beneath the periosteum, and the medullary canal becomes encroached on or obliterated. If syphilitic in origin, it may be due to a central gumma, or to a general condition of sclerosis, developing without any localized focus.

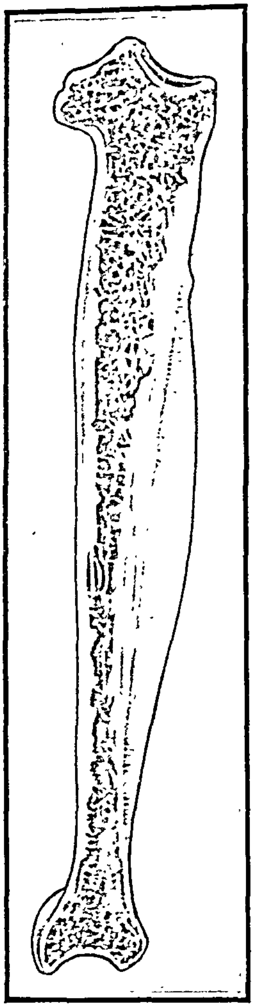


FIG. 360. — CHRONIC OSTEO-PERIOSTITIS OF TIBIA, SHOWING FUSIFORM SWELLING ON THE FRONT OF THE BONE, CONSISTING OF DENSE OSSEOUS TISSUE, AND THE MEDULLARY CAVITY ENCROACHED UPON. (MUSEUM OF ROYAL COLLEGE OF SURGEONS.)

The **Symptoms** consist of deep aching pain in the limb, worse in bed, with perhaps tenderness over some particular spot, especially in cases where an encysted abscess exists in the head of a bone, such as the tibia. On examination the bone is felt to be thickened, and its surface more or less nodulated. If the disease is limited and superficial, a distinct node may be felt, consisting of a hard, fusiform, and tender swelling. Where the enlargement is more general there is less tenderness, though the pain is constant.

The **Diagnosis** of such cases is not always easy, the enlargement of the bone being sometimes mistaken for the *early stage of a malignant tumour*. The rate of growth will be of little assistance, since it is very variable; but a tumour may have more defined limits, and its tension is often not the same throughout. Radiography is valuable in this direction, since in simple chronic periostitis the bone is solid and throws a continuous and well-defined shadow, while in malignant disease a certain amount of soft tissue is always present, either centrally or peripherally, easily penetrated by the rays, and hence leaving gaps in the shadow. If, in spite of such assistance, the case is still doubtful, an exploratory incision will be required.

The **Treatment** consists in resting the limb, applying counter-irritation, *e.g.* iodine paint or the actual cautery, and giving iodide of potassium internally. If relief is not thereby obtained, it will be necessary to cut down over the whole length of the thickened bone through the periosteum, which is stripped aside, and, if merely a nodular enlargement is present, to chisel away

the new formation. When the whole thickness of the bone is involved, a gutter or trench must be made by gouge and mallet, extending into the medullary cavity, and its length corresponding to the enlargement. The soft parts are loosely drawn together; the hollow will fill with blood-clot, which is allowed to organize. If enough bone has been removed, most satisfactory results follow; but in some aggravated conditions which have lasted for many years amputation is required.

Brodie's Abscess is a condition in which an abscess forms in the bone, usually close to the epiphysis, and was originally described by Sir Benjamin Brodie as tuberculous in origin. Although undoubtedly some cases are tuberculous, the majority are staphylococcal in nature, whilst in a few cases a breaking-down gumma is responsible. The abscess cavity, from which often no organisms can be grown, is surrounded by an area of dense bone, densest where the infecting agent is the spirochæte, and least dense where Koch's bacillus is responsible. Usually these abscesses are slowly progressive, although occasionally they may flare up acutely, and in other cases they may become absorbed. They give rise to rather indefinite pain in the region of the affected part of the bone, often worse at night, together with perhaps some periosteal thickening and muscular wasting. Some effusion in the neighbouring joint may be present (Figs. 353 and 354).

Treatment.—All these cases should be subjected to operation, with scraping of the abscess cavity and, if necessary, packing with vaseline gauze, as there is always the danger of the infection bursting into the joint.

Tuberculous Disease of Bone.

Tuberculous disease of bone is secondary to some other tuberculous infection in the body, such as a focus in the mediastinal or abdominal lymphatic glands. It is not commonly associated with pulmonary tuberculosis, but when both are present the outlook is much more serious. The infection is blood-borne, and the tuberculous emboli are held up in the end-arteries on the metaphyseal side of the epiphysis or alternatively enter the epiphysis itself through the vessels derived from the circulus vasculosus of Hunter. Probably some previous trauma has produced a small hæmatoma which provides a suitable nidus for the growth of the tubercle bacilli. Infection may also result through the vessels running from the periosteum into the shaft of the bone. The normal reaction of the tuberculous infection is to produce a typical tuberculous granulation tissue which invades the cancellous bone and the Haversian systems with resulting absorption of the bone, a process known as rarefaction. Sometimes instead of the slow process of absorption the infected area may break down to form tuberculous pus with the production of one type of Brodie's abscess. As has been mentioned previously, this abscess is surrounded by an area of bone which has undergone some degree of sclerosis. This process of the formation of a tuberculous abscess in bone is referred to as *caries suppurativa*. Sometimes the absorption of bone does not keep side by side with its destruction, and partly on account of an

endarteritis obliterans which affects the vessels. Small areas of bone form sequestra, a process known as *caries necrotica*. These sequestra are very different from the hard white sequestra associated with pyogenic infection, being soft and friable, yellowish in colour, light in weight, and often incompletely separated from the surrounding bone. In the small long bones, the vertebræ, and those of the tarsus and carpus, on account of the rapid splitting up of the nutrient vessels, the whole of the bone becomes involved. As in other bones where the periosteum is involved, there is often some periosteal reaction sufficient in *tuberculous dactylitis*, as it is called, to produce an ever-expanding bone which is being continually eroded from the centre. Rarely tuberculosis of bone may give rise to a generalized sclerosis of bone closely resembling that commonly associated with syphilis. If left without any treatment the tuberculous process extends in all directions: outwards to involve the periosteum, the muscles, and eventually the skin with inevitable secondary infection; downwards into the medullary cavity; and upwards into the epiphysis, causing separation and secondary involvement of the joint. Spread outwards may also give rise to joint involvement if the epiphysis is intra-articular, as in the hip-joint. The disease is most commonly seen in children, less commonly in old people, but may occur at any period of life.

1. In **Tuberculous Periostitis** a specific infiltration of the periosteum is met with, consisting of a deposit, partly in that membrane and partly under it, of pulpy granulation tissue containing the characteristic miliary tubercles. As in tuberculous disease elsewhere, caseation and suppuration are likely to follow, leading to the formation of abscesses, which are primarily subperiosteal and filled with curdy pus; these in time find their way to the surface, either directly or by more or less tortuous channels, and leave sinuses, extending down to the diseased area. The effect on the bone may be insignificant if the part affected is dense, consisting merely in some slight superficial erosion; occasionally, however, the disease may spread along the periosteum, and involve a neighbouring epiphysis or joint. If the compact layer is *thin*, as in the sternum, ribs, or bodies of the vertebræ, the underlying cancellous tissue is almost certain to be secondarily affected, and caries will result.

Clinical History.—In a superficial bone a doughy or pulpy swelling forms, which is slightly tender on pressure. It takes weeks or months to develop, and on radiography the underlying osseous tissue may appear quite normal in texture. In the later stages, when caseation or suppuration is present, the swelling often becomes more defined and somewhat resembles an ordinary node, but is more irregular in shape, of somewhat unequal consistency, and on firm pressure small portions may be felt to give way. If an abscess forms, the skin becomes reddened, the swelling is elastic to the touch, and the pain greater, but it diminishes as soon as tension is relieved by discharge of the pus. A sinus, however, forms, and a probe passed down impinges on soft carious bone (Fig. 361). The admission of pyogenic infection increases the trouble.

Treatment.—In the early stages constitutional treatment may suffice, together with rest and carefully-adjusted pressure, as by strapping with Scott's dressing, or Bier's induced hyperæmia, where applicable. The condition, however, demands incision if a neighbouring joint is threatened, or when suppuration has occurred. Free removal of all the granulation tissue and softened bone with a Volkmann's spoon is required, followed by disinfection of the cavity with alcohol and 'bipp,' and, if possible, closure of the wound without drainage. If a rib is involved, it is wiser to remove entirely the affected portion of bone.

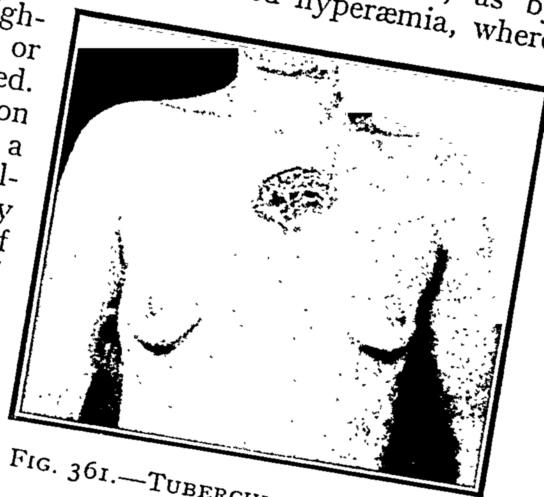


FIG. 361.—TUBERCULOUS DISEASE OF THE STERNUM.
An abscess formed and discharged, leaving a large ulcer.

2. **Tuberculous Osteitis** arises in cancellous tissue, and usually in the epiphyses, or under the articular cartilage. The child complains of pain in the affected bone, often worse after exercise, but beyond this, together with some slight limp and a generally debilitated condition of the child, little else is noticed by the parents. On examination some wasting of the muscles will be observed, and there may be an increase in the temperature of the skin over the area of affected bone. Tenderness can often be elicited, and some effusion into the neighbouring joint may be present. All cases must be confirmed by X-rays, which will show the typical rarefied areas in the neighbourhood of the epiphysis. In the differential diagnosis, subacute osteomyelitis, osteoclastoma, and osteitis fibrosa must be considered.

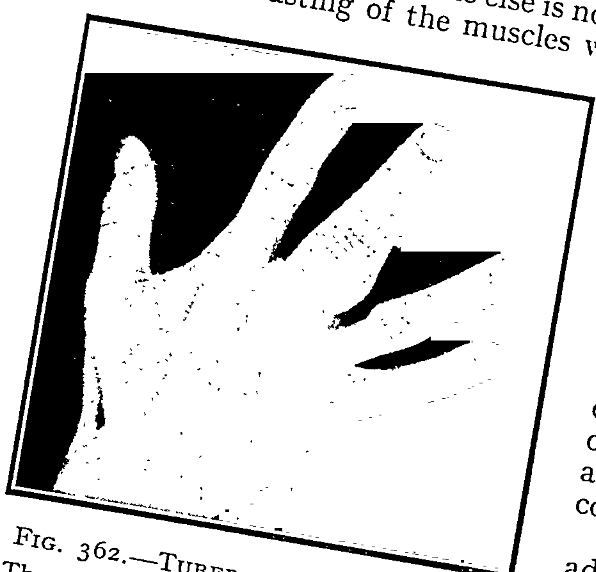


FIG. 362.—TUBERCULOUS DACTYLITIS.
The disease started in the proximal phalanx and has spread to the periosteum.

Treatment.—This consists, in addition to sanatorial régime, in prolonged immobilization of the affected limb, fixing the joints above and below the lesion to produce effective rest. For this purpose splinting with plaster of Paris is the most desirable; the cast can remain on for several weeks before it is changed. The splinting must be maintained for many months; for at least six months after all pain has disappeared and until the X-rays show a return to normal

bony structure. In the case of the leg a walking caliper is worn for another year. If the pain gets worse and in spite of immobilization the X-rays show a spread of disease, operative interference must be considered on account of the danger of involvement of the joint. This will consist of opening up the bone, curetting it, and swabbing it out with pure carbolic, the immobilization then being resumed. If a case of tuberculous osteitis is seen late, where the process has spread outside the bone to involve the surrounding structures and to produce sinuses which have become secondarily infected, amputation may be required. Where a definite Brodie's abscess has formed, operation is indicated to evacuate the tuberculous pus. Prolonged rest in these cases, although giving rise to increasing demarcation of the abscess, will not yield a cure, and the danger of their extension into the joint is too severe a risk to take (Figs. 364 and 365).

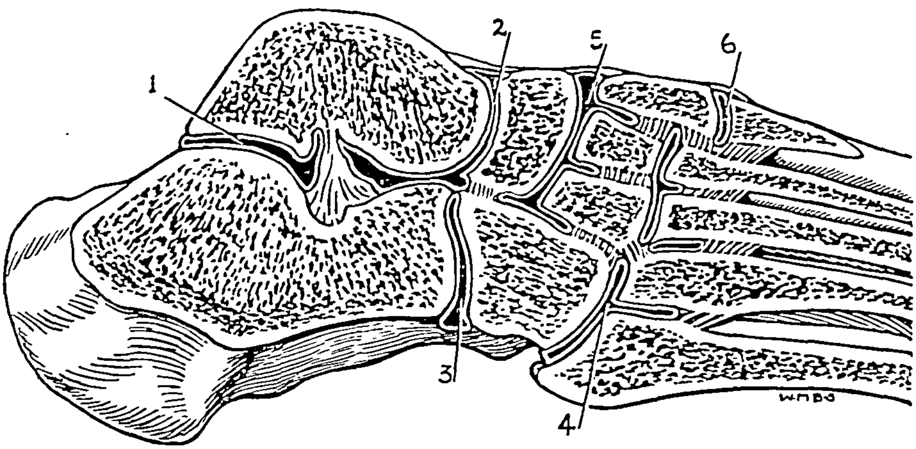


FIG. 363.—ARRANGEMENT OF SYNOVIAL MEMBRANES OF FOOT.

1, Posterior calcaneo-astragaloid, behind the interosseous ligament; 2, anterior calcaneo-astragaloid and astragalo-scaphoid; 3, calcaneo-cuboid; 4, cubo-metatarsal; 5, the large common sac between scaphoid and cuneiform, between the three cuneiform bones, and between the cuneiform and second and third metatarsals; 6, between the internal cuneiform and first metatarsal.

3. **Tuberculous Dactylitis—Clinical History.**—The affected segment of the finger becomes slowly enlarged, bulbous, and painful, the pain being, however, slight in amount, though sometimes worse at night. At first the finger looks white, and the skin is smooth and shiny; but after a time one spot rapidly increases in size, becoming red and tender, and finally an abscess forms, which bursts or is opened, leaving a sinus, down which a probe can be passed into the carious interior of the bone. Occasionally contiguous joints are involved in this process, whilst the tendon sheaths are also liable to be affected; a large portion of the swelling is often due to periosteal infiltration (Fig. 362). In some cases the bone appears to be expanded, but the term *expansion* is scarcely correct, inasmuch as the enlargement is due to absorption on the inner aspect, whilst there is a new formation of bone under the peri-

osteum. Natural cure without suppuration occurs when the child is placed under suitable hygienic conditions, but even then the growth of the phalanx may be hindered, and the finger remains shortened.

The **Treatment** of tuberculous dactylitis must be conducted along the lines laid down for tuberculosis generally on p. 175. The child is transferred to some healthy place where treatment of a sanatorium type is possible, and there it must remain, perhaps for years, until the trouble comes to an end; educational facilities must therefore be included in the programme. The local treatment consists in putting the hand to rest on a splint, and possibly applying Scott's dressing to the affected finger. There is but little call for operative treatment under such circumstances. If an abscess forms, it should be aspirated at an early date, so as to avoid the risk of sinus formation. In the worst cases where pyococcal troubles are also present, amputation may be required.

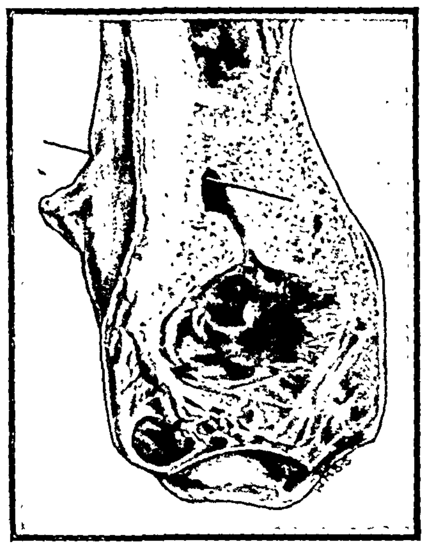


FIG. 364.—CHRONIC ABSCESS IN THE LOWER END OF THE TIBIA. (KING'S COLLEGE HOSPITAL MUSEUM.)

Any of the *bones of the tarsus* may be involved in exactly the same manner, the clinical history and treatment being identical, although articular lesions are more common than when the disease is limited to the phalanges. The affected portion of the foot becomes swollen and shiny, since the overlying periosteum is often involved in the process; and it is sometimes difficult to determine whether the lesion is limited to the bones or involves the joints also. In the early stages one part of the foot may be more swollen than another, according to the location of the trouble. The os calcis is most often affected, and afterwards, in order of frequency, come the first metatarsal, astragalus (the head), and scaphoid. When it starts in the astragalus, the swelling occurs below the level of the ankle-joint in front of or behind the malleoli, whilst pressure over the head of the bone gives rise to pain. The foot is usually in a position of equinus, but not to such a marked degree as when the ankle-joint itself is affected; the subastragaloid movements (inversion and eversion, abduction and adduction) are also considerably limited, or may be absent. An examination of the accompanying illustration (Fig. 363) will explain the fact that tuberculous disease starting in the astragalus is very likely to involve the ankle-joint, or to spread to the os calcis or scaphoid. Disease of the os calcis leads to more limited swelling of the back of the foot on one or both sides of the heel; the movements of the ankle will not be impaired, although walking is painful, and hence the patient limps, treading only on the toes. Further forwards, tuber-

culous disease is most likely to start in or around the scaphoid, the bulbous swelling of the foot being then shifted anteriorly, and the movements of the ankle remaining unimpaired. Owing to the arrangement of the synovial membranes, the prognosis is much worse when the disease attacks the inner half of the foot, comprising the astragalus, scaphoid, cuneiform, and three inner metatarsal bones, than when it affects the outer segment, consisting of the cuboid and two outer metatarsals, which are excluded from the general synovial membrane, and are thus more amenable to treatment.

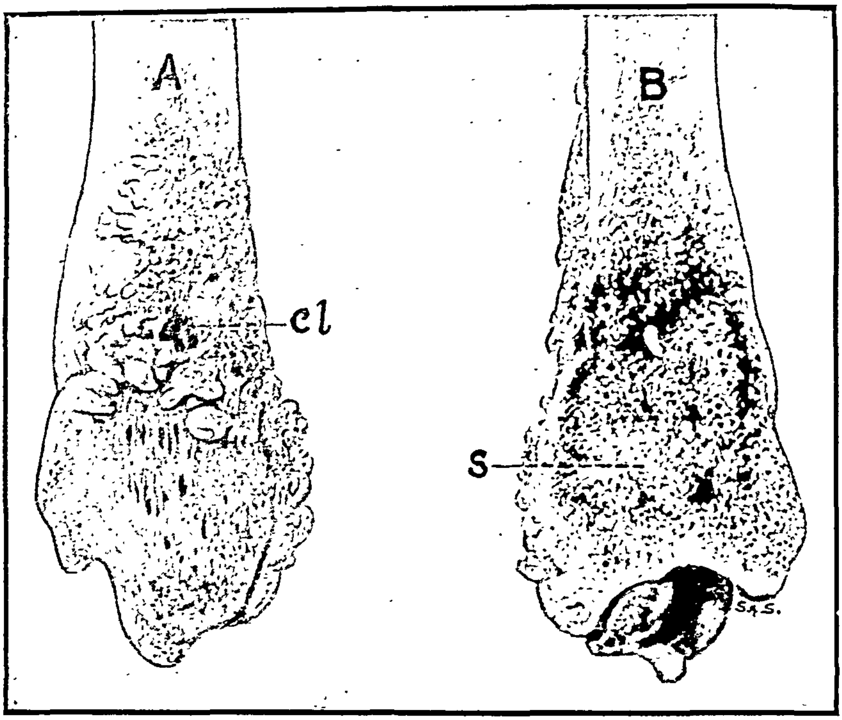


FIG. 365.—LOWER END OF TIBIA AFFECTED WITH TUBERCULOUS DISEASE. (KING'S COLLEGE HOSPITAL MUSEUM.)

In A, a subperiosteal deposit of new bone is seen surrounding an opening (*cl*), which leads into the interior of the bone; in B, the interior of the same bone is seen, and shows a sequestrum (S) just above the epiphyseal line. The ankle-joint is healthy.

The **Treatment** consists in the usual local and constitutional measures adopted in tuberculous disease (p. 175). In the early stages the foot and ankle are immobilized, and preferably in plaster of Paris, and the foot is not allowed to be used until all pain has ceased. Older patients are fitted with a Thomas's knee-splint and a patten, and allowed to get about on crutches.

Should the disease persist, or suppuration recur after aspiration, operation may be required. If the *os calcis* alone is involved, it will suffice to open it from one or both sides, to scrape out and disinfect its interior, with subsequent closure of the wound. If the disease

mainly affects the *astragalus*, it may suffice to remove it entirely, neighbouring articulations being curetted; but probably the disease will have spread so far that Syme's amputation will be required. Disease of the *cuboid* and outer half of the foot in front of the os calcis can often be dealt with efficiently by scraping, but when the common synovial membrane on the *inner side* is involved, and hygienic treatment fails, amputation will probably be needed.

For tuberculous osteomyelitis of ribs, see p. 685.

Syphilitic Diseases of Bone.

In the **Secondary Stage** flying pains about the bones (sometimes termed *osteocopic*) are often complained of; they are, however, of but little importance, and disappear rapidly as the patient gets under the influence of treatment. In the late secondary or early tertiary periods a *periosteal node* is often met with, as a result of chronic periostitis. It usually affects only one bone, and most commonly the tibia, and consists of infiltration and thickening of the periosteum, which may entirely disappear or be followed by a formation of new bone, which is at first spongy and soft, but after a while becomes hard and sclerosed. When this has once occurred, absorption of the newly-formed bone does not readily follow, even under treatment, the part remaining permanently thickened. It is recognized clinically as a fusiform swelling, a little tender on pressure, and the seat of deep aching pain, usually worse at night. It must be understood that the pain is not so much associated with the onset of night as with the increased warmth of the limbs when in bed; indeed, patients with syphilitic tibiæ frequently sleep with their legs exposed. Night-watchmen and others, on the contrary, complain of pain during the day, when they take their rest. Suppuration does not occur, and constitutional rather than local treatment is required.

In the **Tertiary Period** the bones may participate in the changes which involve any and every tissue of the body. The following lesions are described, but are nowadays rarely seen:

(*a*) The formation of *subperiosteal gummata*, either localized or diffuse, probably resulting in *caries* of the subjacent bone; if the affection is limited, only a small portion may be thus involved; but where it is widely diffused, an extensive surface of the bone may become eroded and irregular. This process is sometimes accompanied by a development of new bone under the adjacent periosteum, and even by sclerosis and necrosis. The calvarium is the part most frequently involved, and as but little new bone forms in this situation the skull often presents a curiously pitted or worm-eaten appearance (Fig. 366). The overlying scalp is usually invaded and destroyed by the gummatous process, permitting the entrance of pyococci; deep and sometimes extensive wounds result, discharging foul pus, and at the bottom of which bare and even dead bone may be felt.

(*b*) At the same time a condition of *sclerosis* may develop in the underlying or surrounding parts, and this to such a degree as seriously to compress and constrict the vessels in the Haversian canals. Moreover, an obliterative endarteritis is almost always present, and these

factors, combined with the separation of the periosteum and the influence of the mercury administered for therapeutic purposes, so interfere with the vitality of the bone that, should pyococci be admitted, necrosis is almost certain to ensue.

The effects produced vary considerably in different cases, and especially with the situation. When the *calvarium* is attacked, pyogenic infection often supervenes, owing to the thinness of the scalp and the depth to which the hair follicles penetrate, and consequently necrosis is common. The process in such a case is probably as follows: The pericranium corresponding to the necrotic area becomes gummatous, and at the same time the subjacent bone undergoes sclerosis. Sooner or later the gummata burst or are opened; pyogenic

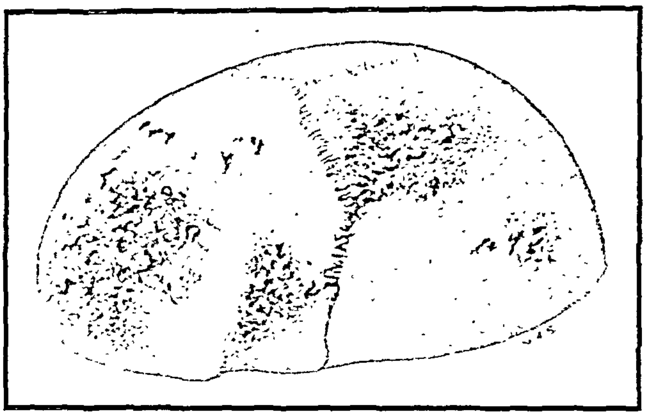


FIG. 366.—SYPHILITIC CARIES OF SKULL FROM DIFFUSE GUMMATOUS DISEASE. (FROM KING'S COLLEGE HOSPITAL MUSEUM.)

infection occurs, and the scalp tissues are stripped off the calvarium to the limits of the disease, necrosis resulting in the sclerosed area of bone. A line of rarefaction subsequently forms around the sequestrum in consequence of Nature's attempts to separate it. The later stages of the disease are marked by extreme chronicity, the sequestrum lying bare in the wound perhaps for years without being separated, owing to the slight degree of vascularity and the extreme condensation of the surrounding parts. It is quite unusual at the present day to see cases of this nature. In the *shafts of long bones*, where the compact tissue is thick and resistant, there may be extensive periosteal disease, with but little affection of the underlying parts; but if this compact layer is thin, and especially when the cancellous ends are involved, a considerable amount of destruction from caries may result, though if pyococci are not admitted there will be an entire absence of necrosis.

The *sternum* is not uncommonly affected by syphilitic disease, which manifests itself as a gumma, which breaks down and suppurates, but does not often cause much bone destruction. The *nasal bones* and *hard palate* are frequently the site of subperiosteal gummatous formation, resulting in suppuration and necrosis; a foul discharge from the nose results in the former case, which may be followed by destruction of the septum nasi and permanent deformity. The palatal trouble often results in perforation.

In the **Treatment** constitutional remedies must be employed, and will be valuable if suppuration and necrosis have not occurred. They may have but little effect, however, if pyogenic infection has supervened, apart from measures directed to providing effective drainage and removal of the dead bone. In the calvarium, however, no attempt should be made to take away the dead bone unless it is loose.

(*c*) Occasionally a *gummatous osteomyelitis* is met with, in which a gumma forms in the interior of a bone. It results in the so-called expansion of bone and secondary thickening, *i.e.* a chronic osteoperiostitis, limited usually to one end of the bone at first, but subsequently affecting the whole shaft. It has often been mistaken for malignant disease, and amputation considered or undertaken. The greater rapidity of growth in the syphilitic cases, and the evidences of tertiary lesions elsewhere, or of a syphilitic history, and the existence of a positive Wassermann reaction, will often guide the surgeon to a right conclusion, whilst radiography is also helpful; but if there is any doubt an exploratory incision and a microscopic examination of the diseased tissues should always be made before amputation is undertaken.

In **Inherited Syphilis** any of the above manifestations may be seen, but with more or less special features added, and, in addition to these, certain forms which do not occur in the acquired type of the disease have been described.

1. A new formation of bone beneath the periosteum is perhaps the most frequent result, and this occurs with but little pain. Perhaps the most common situation of this lesion in infants is the calvarium, where bony masses known as *Parrot's nodes* form around the anterior fontanelle, causing the top of the skull to resemble a 'hot-cross bun' in shape. In the early stages the bone is soft and spongy, and on post-mortem examination is dark red or maroon in colour. If the process is not checked by suitable antisyphilitic treatment, the newly-formed osseous tissue becomes dense and sclerosed, and the deformity may then persist through life (Fig. 48, p. 157). Any part of the calvarium may, however, be affected, and the change is not necessarily limited to the first years of life.

2. A somewhat similar condition is met with in the shafts of long bones, due to the deposition of alternating lamellæ of soft and hard bone outside the ordinary compact tissue and beneath the periosteum.

3. *Syphilitic epiphysitis* (or, as it is termed, syphilitic *osteochondritis*) is a lesion characterized by enlargement of the ends of the bones, as in rickets, but coming on within the first year after birth. The enlargement is mainly situated in the epiphysis, but also extends some way along the shaft, thus contrasting forcibly with rickets. Occasionally only one side of the epiphysis is affected. The change commences in the zone of calcified cartilage nearest the diaphysis, which becomes friable, opaque, and irregular, and as the condition progresses it may be transformed into granulation tissue, so that separation of the epiphysis follows. Pyogenic infection may follow, resulting in suppuration and necrosis of the epiphysis or acute arthritis, or the limb hangs powerless in a condition known as *syphilitic pseudo-paralysis*. The disease is usually symmetrical, and often multiple,

and situated in much the same positions as rachitic affections, the knees, elbows, and wrists being perhaps most often affected. It may terminate in the early stages, and be followed by organization of the granulation tissue, the ultimate result being cessation of growth in the bone.

4. A symmetrical overgrowth of the tibia, perhaps combined with an anterior curvature, also occurs in syphilitic children, resulting in permanent elongation of the legs (p. 511).

5. *Craniotabes* consists of a localized absorption of the osseous tissue of the cranium, leaving small areas where the bone is thinned or absent, so that on pressure a sensation of crackling, like that of parchment, is imparted to the finger. It occurs most frequently in the parietal bone, and in the majority of cases within the first six months of life, a fact that throws considerable doubt on the idea that it is due to rickets.

The **Treatment** of syphilitic lesions in children must be carried out in accordance with general principles, and mainly by the administration of suitable drugs.

Rickets.

Rickets is a disease occurring in children and manifesting itself mainly in lesions connected with the bones. It usually commences within the first three years of life, but sometimes appears later.

Causes.—Much work has been undertaken during recent years to solve the ætiological problem of rickets, and it now seems certain that at least three elements combine in order to bring about the disease: (1) Deficiency of the *antirachitic vitamin D* in the diet; it is present in good milk, eggs, and butter, but apparently the amount in milk varies with the diet and management of the cow, being more abundant when the animal receives fresh green food and lives in the sunshine. Cod-liver oil contains the largest amount of antirachitic vitamin of any known substance. (2) *Sunlight*, and especially the ultra-violet rays in the spectrum, are essential if healthy bone formation is to occur. The abundance of sunshine of the tropics explains the rarity of rickets in these regions, and the nature of the food available in the Arctic circle, largely blubber, provides the antirachitic factor which balances the lack of sunshine there experienced. (3) A sufficiency of both *calcium and phosphorus* must be present in the food if healthy bone is to be formed. Good milk contains an abundance of these in a suitable form, but cannot prevent rickets apart from other factors. When the diet consists largely of cereals or carbohydrates, defective intake of Ca and P may have a distinct causative influence.

Rickets is therefore a deficiency disease, induced chiefly by improper or insufficient food, especially by the too early administration of starchy materials and the want of suitable fats, whilst uncleanliness and the absence of sunlight and fresh air predispose to it. The crowded streets and houses of the poorer sections of our great cities are obviously magnificent factories of this disease. Syphilis has no direct causative connection with rickets.

The **Symptoms** may be divided into the early or general, and the later or osseous. The *general* symptoms commence with the child

becoming feeble and fretful, losing its power of walking if this has been attained, and its muscles generally are hypotonic. The child may be fat and flabby, or thin and emaciated; the mucous membranes are pale, and vomiting and diarrhœa are constantly present, the motions being often green, slimy, and very offensive. The spleen is enlarged, the abdomen tumid, and profuse sweating of the head is very characteristic.

The commencement of the *osseous changes* is usually indicated by increasing irritability and restlessness, the child tossing off his bed-clothes at night, and crying out when handled or touched. The articular ends of the long bones become enlarged, as also the junction of the costal cartilages with the ribs. Sooner or later the shafts of the long bones soften, and may bend in various directions, and thus many *deformities* may be produced.

FIG. 367.—CHILD WITH WELL-DEVELOPED RICKETS.

The enlargement of the epiphyses of the radius and tibia is well seen.

The *head* usually becomes flattened antero-posteriorly, so that the forehead appears square in shape and enlarged, whilst frontal bosses may develop on either side, due to new formation of bone under the periosteum; it is a question, however, whether these are not syphilitic rather than rachitic in origin. The fontanelles remain open much longer than usual, and craniotabes is said to occur. The teeth do not erupt till late, and are stunted, defective in enamel, and easily eroded, so that the ends of the incisors are often concave; they must not be mistaken for syphilitic teeth, since the concavity is a small arc of a large circle, while the typical notch of syphilis is a large segment of a small circle.

The *spine* may be affected by kyphosis (p. 491), or less frequently by scoliosis (p. 486); the kyphotic curve results when the patient is allowed to lie too much in bed with the head on a high pillow, or if the child is carried about with a curved back; scoliosis more often occurs when the patient is able to walk (Fig. 367). Occasionally a kypho-scoliosis is produced as a result of the child being carried about sitting on a nurse's arm with the pelvis tilted.

Changes in the *thorax* are produced by enlargement of the costo-chondral junctions (*beaded ribs*), which, when present on either side of the sternum, produce what is known as the *rickety rosary*. The swelling is more marked on the pleural aspect than on the outer side

of the bone. If there is any obstruction to the entrance of air into the lungs, as from tracheitis or bronchitis, the atmospheric pressure may cause the softened bone and cartilage to sink inwards, and as a result of this the sternum may be pushed forwards (*pigeon breast*), whilst the curvature of the ribs at the angle is increased. A very characteristic feature of the rickety change consists in the lateral groove thus produced on each side of the sternum, which may meet with a transverse depression below, caused by the projection of the lower floating ribs by the tumid abdomen.

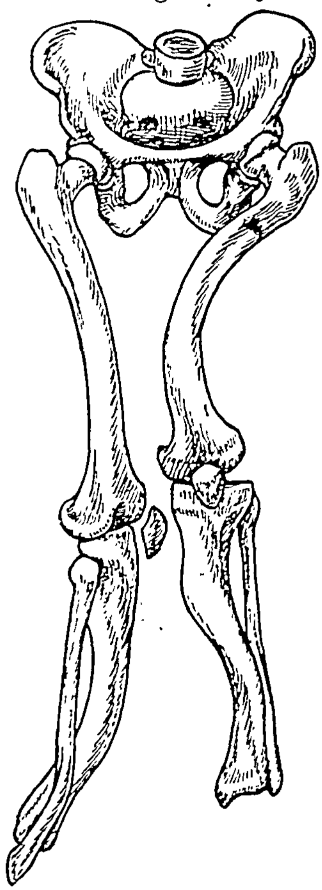


FIG. 368.—PELVIS AND LEG BONES IN RICKETS. (FROM COLLEGE OF SURGEONS MUSEUM.)

FIG. 369.—X-RAY OF WRIST OF CHILD WITH RICKETS.

The *pelvis* is flattened antero-posteriorly, or more rarely is triradiate, the former condition being produced when the patient lies habitually on his back, the latter occurring only when walking is permitted, the acetabula being then pressed inwards and backwards by the heads of the femora.

The deformity of the *long bones* (Figs. 368 and 370) usually consists in an increase of their natural curves, especially at points where powerful muscles are attached. The femora are curved forwards

and outwards, and the tibiæ in a similar direction, although not uncommonly the lower end of the tibia is bent inwards. Genu valgum or varum may also result from these changes (pp. 507 and 509).

When the acute stage of rickets has passed away, any deformities present become fixed by the complete ossification of the softened bony tissues. As a rule the density of such deformed bones is increased, whilst their natural shape is altered by deposits of new subperiosteal bone or struts in the concavities, so that on section they are usually more or less flattened from side to side, and the medullary canal appears to be displaced towards the convexity. Growth is often checked by this disease, and thus the individual becomes stunted and dwarf-like.

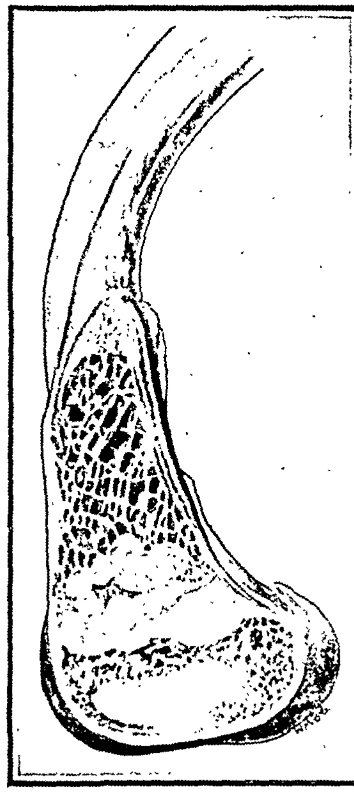


FIG. 370.—SECTION THROUGH LOWER END OF RICKETY FEMUR, SHOWING EXAGGERATED DEPTH AND IRREGULAR BORDERS OF THE PROLIFERATING EPIPHYSEAL CARTILAGE. (COLLEGE OF SURGEONS MUSEUM.)

Pathologically the chief changes in rickets are found in the neighbourhood of the epiphyses. Ordinarily, the epiphyseal cartilage is a lamella about a line in thickness, bounded on either side by a zone of calcified tissue, containing regular alveolar spaces filled with vascular medulla, and lined by osteoblasts, passing gradually into normal cancellous bone. In rickets the epiphyseal cartilage is not only circumferentially enlarged, but also thickened and irregular (Fig. 370), outgrowths of cartilage projecting on either side into the calcified tissue, which is more abundant and more open in texture than usual, whilst it passes irregularly into the cancellous bone. Thus, there is an increased preparation for the formation of bone, but the ossifying process is inefficiently carried out. X-ray examination shows the typical deformity at the end of the bones (Fig. 369). In addition to this, the Haversian canal systems and the medullary spaces in the diaphyses are enlarged, so that the bones become weaker and less rigid from the insufficient amount of lime salts present, and thus readily bend under the weight of the body or from muscular action. Less frequently the subperiosteal compact bone becomes similarly rarefied. When the disease comes to an end the deformities may persist, but the bone, now effectively ossified, becomes harder and stronger than usual.

In the **Treatment** of rickets the most essential feature in the early stages is the correction of all errors in the personal hygiene. The diet should consist of good cow's milk, diluted if need be, and with lime-water added; whilst the juice expressed from raw beef, or one of the many meat juices now sold, may also be administered. The

condition of the bowels must be attended to, and the child placed in as good surroundings as possible. Cod-liver oil is the all-essential medicine, containing an abundance of the necessary .antirachitic vitamin; it may be administered in combination with Parrish's food (syr. ferri phos. co.). Exposure to sunshine is perhaps best delayed until the general symptoms of the acute stage have passed; if it be not obtainable, the ultra-violet rays of the arc lamp should be substituted. Deformities should be prevented by keeping the child in the recumbent posture, and not allowing it to crawl or run about. The early stages of deformity can often be corrected by daily manipulation of the affected bones; for the legs, it may suffice to keep the child off its feet, as by a splint which extends from the thighs 6 inches below the soles; a certain amount of pressure can also be exercised by this appliance. Osteotomy, or even resection of portions of bone, is required in the severer cases where the deformity persists, and the bony changes have become consolidated (see p. 511).

Adolescent Rickets comes on about puberty, and is usually independent of an early rachitic history, although in a few cases it may be looked on as a recrudescence of the infantile ailment. Imperfect nutrition is probably a less important ætiological factor than in infancy; but strain, mental or physical, combined with defective hygiene, has been present in most instances. The chief changes are to be found in the shafts of the long bones of the legs, which become bent from the superjacent weight of the body. Deformities in the upper extremities are less frequent. Enlargement of the epiphyses is also observed. There is usually no sweating of the head, but the patient is pale, and complains of fatigue and languor, but not of pain. The softened bones bend, and no buttresses or struts are formed in the concavities; hence the deformities produced are often serious, and the course of the case is slow. *Treatment* is undertaken along the same lines as for the infantile variety, cod-liver oil and sunshine being the two essentials; undue mechanical strain must be avoided, and, if need be, the patient is kept at rest. Deformities are dealt with by the use of orthopædic appliances or by osteotomy.

Infantile Scurvy (*syn.*: **Barlow's Disease, Scurvy, Rickets, Hæmorrhagic Rickets**).—This condition, first accurately described by Sir Thomas Barlow, presents the symptoms of scurvy in a rachitic child, and in its manifestations either one or the other set of phenomena may predominate. It is usually seen in the children of well-to-do people from four to eighteen months old, and apparently arises from defective nutrition, especially from the prolonged administration of peptonized or prepared foods, or even possibly of sterilized milk. In the slighter cases there may be but little evidence of the scorbutic condition, beyond the fact that in a rickety child there is some tendency for the gums to bleed, or a little hæmaturia; but in those that are more marked the rickety signs are of little importance compared with those due to hæmorrhagic extravasations. The disease often comes on suddenly with some amount of pyrexia, rarely exceeding 102° F., but the child is evidently ill, and perhaps complains of tenderness of the limbs, which may be kept so quiet as to suggest that they are paralyzed. This is followed by the appearance of swellings of some

size, due to sub-periosteal extravasations, the skin over the affected parts being at first shiny and œdematous, but subsequently becoming stained by the blood-pigment. The femur and tibia are most often affected in this way, and the epiphyses occasionally become detached, or even spontaneous fractures may occur. Bleeding may also take place beneath the conjunctiva or in the orbit, leading to protrusion of the eyeball, whilst there may be blood-stained diarrhœa, hæmaturia, or epistaxis.

The disease, when recognized, is readily amenable to *treatment*, but should its nature be overlooked, the child is likely to become emaciated and die. Attention to the diet is the main point to be attended to, for when fresh milk, lime-juice, or vegetables are given, the symptoms soon disappear. The affected limbs must be kept at rest, and cooling lotions applied, whilst splints are required when epiphyses are separated or fractures have occurred.

Achondroplasia (Chondrodystrophia fœtalis) is a curious congenital condition, somewhat resembling rickets, in which the growth of those bones developing from cartilage is cut short and interfered with by virtue of premature synostosis with the epiphysis. The growth of the long bones of the arms and legs is grossly affected, so that the limbs are short and stunted, and the stature correspondingly diminished, although the epiphyses are normal. The bones generally are not bent or curved abnormally, though there is probably some change of the neck or shaft of the femur, resulting in lordosis, which is very marked when the patient stands. The fingers taper to their tips, and are separated one from another in 'spoke-like' fashion. The bones at the base of the skull, being of cartilaginous origin, undergo premature synostosis, whilst the upper half of the skull, being derived from membrane and therefore developing naturally, looks unusually large; the face is small, and the bridge of the nose depressed as in congenital syphilis, on account of the premature ossification of the scaphoid. The children, if they live, are usually efficient in their mental development, and the thyroid body normal. No known treatment is of any value.

Renal Dwarfism was first described by Barber in 1913, and is of interest to the surgeon owing to the fact that in about 70 per cent. of cases there are bony deformities. The disease is characterized by severe chronic interstitial nephritis associated with deformities of the limb bones, which make their appearance from the eleventh to the fourteenth years. The changes in the bones resemble those of rickets, but the X-ray appearances are distinctive and characteristic. Skiagrams show a much greater regularity of the epiphyseal line as compared with rickets, although the detail is frequently blurred owing to osteoporosis. The deformity is not due to bending the shaft of the bone, but to displacement at the epiphyseal line.

Renal Rickets is sometimes seen as a complication of congenital cystic disease of the kidneys (Fig. 371).

Osteogenesis imperfecta (or **idiopathic psathyrosis**) is a rare *congenital* condition, characterized by a defective development of osseous tissue from cartilage, so that the bones are brittle or soft, and thus are easily

bent or broken, constituting a condition of *fragilitas ossium*. Nothing is known as to ætiology, except that there is a strong hereditary tendency. It is possibly due to some change in the parathyroid glands, which apparently control the calcium metabolism. Not a few of the subjects are stillborn, with broken or deformed limbs, whilst many die within the first year of life. Cases in which fractures occur more or less spontaneously and frequently in older life are probably due to some other condition, such as osteomalacia. If the child lives, one fracture occurs after another and the limbs may become terribly deformed, although with care they usually unite well. In addition to the deformities due to the malunion of fractures, the bones are usually bent and distorted, and thus the case may be confused with rickets or osteomalacia. The cranial bones sometimes participate in the process, and are deformed; the sclerotics are of a bright blue colour. The actual anatomical changes in the bones consist in the persistence of cartilage cells in their capsules and calcification of the trabeculæ between, very little bone being formed, and that of a defective type. The administration of parathyroid extract is justifiable, and calcium salts may be useful; otherwise, all that can be done is to protect the patient from mechanical injuries and treat the fractures as they occur.

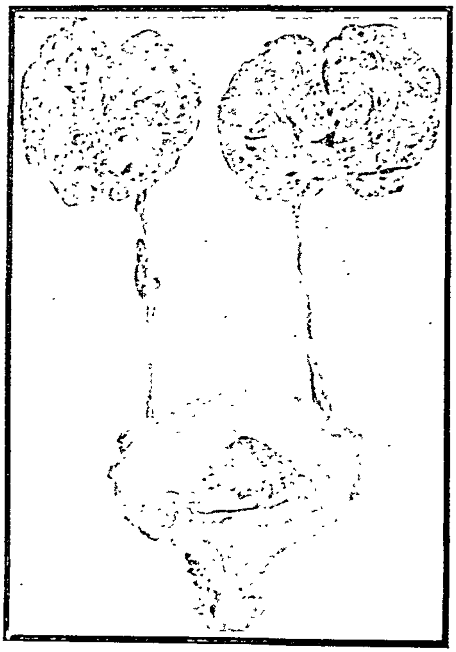


FIG. 371.—CONGENITAL CYSTIC DISEASE OF THE KIDNEYS IN A CHILD SUFFERING FROM RENAL RICKETS.

Mollities Ossium (*syn.*: **Osteomalacia**) is an *acquired* disease of somewhat unusual occurrence, characterized by the absorption of the osseous substance of the bones, as a result of which softening and rarefaction are produced, followed by bending or spontaneous fracture. The complaint is almost limited to the female sex (only 8 per cent. of the cases reported are in males), and often commences during pregnancy; it is said to be sometimes connected with a rheumatic tendency. Any part of the skeleton may be affected; in females the change usually attacks the pelvis, spinal column and ribs first, and the limbs later; in men the process starts in the long bones.

Pathologically, the change consists in a replacement of the medullary substance by a soft fibro-cellular tissue, which is exceedingly vascular, and into which hæmorrhage often occurs; the resulting material looks in the fresh state somewhat like splenic pulp The bony cancelli are absorbed, as also the greater part of the compact tissue, with the exception of a thin layer situated beneath the periosteum; in a well-

marked case the mineral salts may be diminished to about one-sixth of their normal amount, but the relative proportion of phosphate of lime to the carbonate is not changed. Part of the bone substance remains for a time in a decalcified state, with the corpuscles evident, but in a condition of fatty degeneration. Possibly some acid, *e.g.* lactic acid, is the active agent in dissolving the earthy salts, which escape partly in the urine, partly in the fæces. The disease is undoubtedly due to a deficiency in the circulating blood calcium, a deficiency which the body attempts to make good by the mobilization of the bone calcium. The deficiency may be due to a deficient intake or a period of relatively deficient intake such as may occur during pregnancy, where the demands for calcium in the milk and in the skeleton of the fœtus are great. Deficient absorption, as occurs in cases of idiopathic steatorrhœa, may give rise to this condition. Lack of vitamin D, which is intimately concerned with the absorption of calcium, is also a potent factor in this disease.

FIG. 372.—PAGET'S DISEASE OF THE TIBIA.

Note the broad, hazy trabeculæ, alternating with areas of rarefaction, which tend to be pointed at their extremities, together with the bowing of the bone.

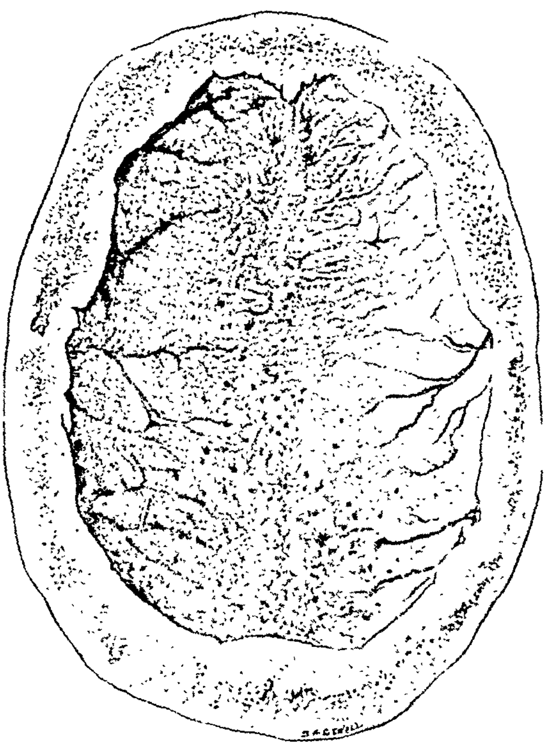


FIG. 373.—CALVARIUM IN OSTEITIS DEFORMANS. (ROYAL COLLEGE OF SURGEONS MUSEUM.)

Clinically, the onset is somewhat indefinite, the only complaint being of pain in various parts of the body, whilst the patient becomes

emaciated and exhausted. Sooner or later skeletal changes ensue and demonstrate the character of the disease. In women the mischief usually commences in the pelvis, which becomes flattened at first, and subsequently triradiate, owing to the acetabula being pressed inwards and backwards by the weight of the body, and in pregnant women this may cause so much deformity as to necessitate Cæsarean section. The spine becomes curved, whilst the limbs bend and break; in the latter case sometimes no attempt at repair is made, or healing may occur with deformity. Death may result from exhaustion, or from obstruction to parturition, or the patient may live more or less bedridden for years, the limbs becoming useless, shortened, and perhaps contorted in a strange and abnormal fashion. In women the disease may cease to progress, or even recovery may occur at the menopause.

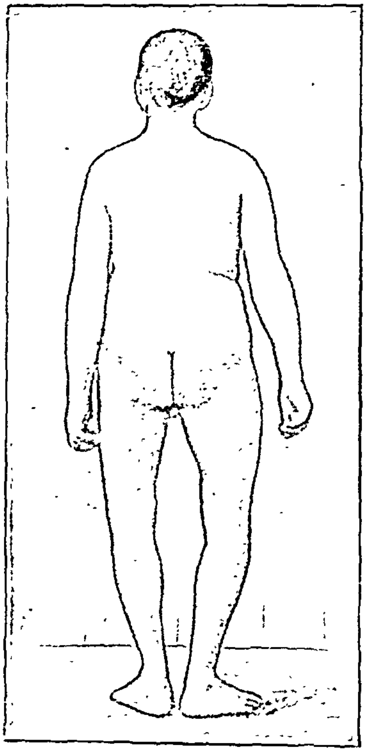


FIG. 374.—EARLY STAGE OF OSTEITIS DEFORMANS.

Treatment consists of the administration of a diet containing requisite quantities of calcium together with vitamin D and the exposure of the body to sunlight or ultra-violet radiation. During treatment and until a cure is effected the stresses to which the bones are subjected should be reduced to a minimum in order to avoid deformity.

Osteitis deformans is an inflammatory disease of the osseous skeleton, first described by Sir James Paget in 1876. The onset is insidious, and the progress very slow. It is characterized by a painful overgrowth of the long bones, spine, cranium, and pelvis, which are also softened, so that those which bear the weight of the body become curved. It may commence in one bone alone, and then usually the tibia or femur, but more often many bones are affected at the same time (Fig. 372). Attention may be drawn to the condition, either by the pain, which the patient at first considers to be rheumatic, or by the general enlargement and bending of the bones, or by the increased size of the head, necessitating the use of larger hats. The cranial overgrowth is eccentric in character, and the calvarium may become very thick (Figs. 373 and 375); the facial skeleton, however, is not much affected (Fig. 376). The spine becomes markedly kyphotic (Fig. 374), the dorsal curve being increased, and the lumbar concavity obliterated; it is nearly rigid from ankylosis of the vertebræ, and may be very painful. In the later stages the head is carried forwards by the bent spine, the height is diminished, the shoulders are round, and the chest sunken towards the pelvis; the gait is slow and awkward.

The disease usually attacks middle-aged men; its progress is exceedingly slow, the patient often living to an advanced age, or dying from some intercurrent malady. Some cases have terminated in sarcoma or endothelioma of the bones. The structure of the osseous tissue is suggestive of inflammatory rather than degenerative changes. There is an invasion of the compact and cancellous bone by a very vascular connective tissue with subsequent loss of demarcation between these two layers of the bone. It is during this process that fractures of the bone may occur. Later osteogenic activity supervenes, and there

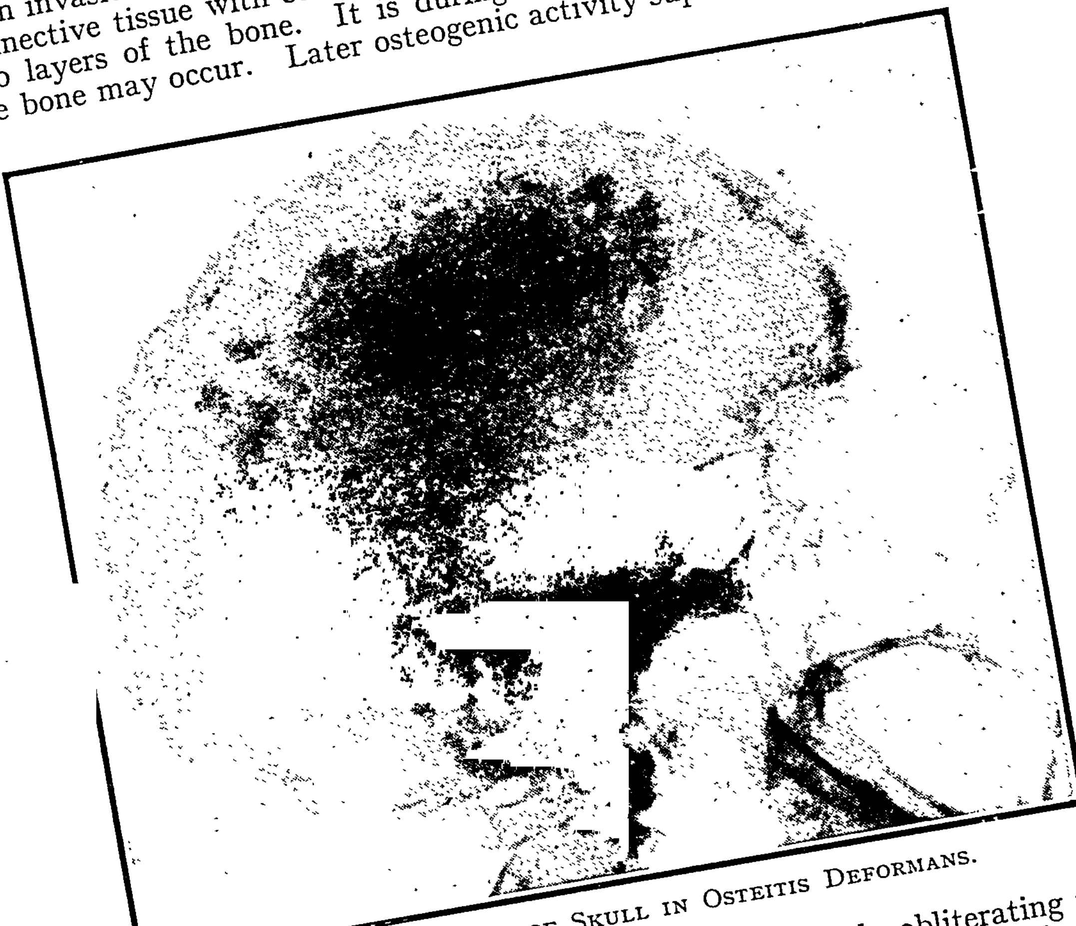


FIG. 375.—SKIAGRAM OF SKULL IN OSTEITIS DEFORMANS.

curs the formation of many bony trabeculæ partly obliterating the edullary cavity and giving rise to a bone with an immensely thickened ortex.

Differential Diagnosis.—From *arthritis deformans*, which it resembles by the attitude and gait of the patient, it is known by the absence of articular lesions, especially in the fingers, and the enlargement of the bone, notably of the cranium. From *acromegaly* it is distinguished by the absence of enlargement of the hands, feet, and lower jaw.

Treatment is purely symptomatic, no remedy at present known having any control over the disease.

Generalized Osteïtis Fibrosa (von Recklinghausen's disease) is a condition associated with a disturbance of the calcium metabolism

of the body dependent upon over-activity of the parathyroid. The disease is more common in women, occurring most frequently about the age of forty to fifty, and is usually accompanied by severe pain in the affected bones with associated general malaise and debility. Sometimes the patient may attend with a fracture sustained as a result of some quite trivial violence, at others a tumour may be noticed, often in the jaw, and sometimes hæmaturia may bring the patient to the doctor. In this disease there is a steady absorption and softening of the bone and replacement by vascular connective tissue, with the result that fractures and other deformities occur as a result of the stresses to which these weakened bones are subjected. In this mass of fibrous tissue there are scattered small islands where calcification and ossification have taken place so that the bone cuts with a gritty sensation. Cysts varying in size from a small pea to a plum are common throughout the bones affected and are filled with a reddish-brown fluid probably representing degenerated fibrous tissue. Giant-cells are seen scattered in areas throughout the general granulation tissue of the bone. Examination of the blood calcium shows this to be raised to anything up to 23 mgm. per 100 c.c., this being quickly reduced to normal with an accompanying return to a normal condition of the bones on removal of the parathyroid adenoma always present in this condition.

A single cystic degeneration sometimes occurs, usually in young people, and most commonly in the upper end of the femur or humerus. It is known as *focal osteitis fibrosa cystica* and is associated with no enlargement of the parathyroid or disturbance with calcium metabolism. The cyst is lined with reddish granulation tissue and contains numerous giant-cells. Fracture of the affected bone is often the initial symptom. **Treatment** consists in exploration of the cyst, curetting it and packing the cavity with masses of bone chips. This is followed by a period of suitable immobilization.

Acromegaly is a rare condition, the characteristics of which were first described by Dr. Pierre Marie in 1885. It is a general affection involving mainly the osseous system, commencing usually in young adults, and, after lasting for a long time, killing the patient by syncope or cerebral compression, if some intercurrent malady does not destroy him.

It is characterized by a very definite enlargement of the hands and feet, which are, however, not lengthened, so that the hands have been compared to battledores and the fingers to sausages. The bones themselves are enlarged; and the soft structures on the palmar aspects project as pads. The nails and skin are unchanged, whilst the other segments, both of the upper and lower limbs, are usually unaffected, though sometimes considerable overgrowth in length occurs; in fact, many of the so-called giants who have been exhibited are typical illustrations of acromegaly. Both the upper and lower jaws are thickened and prominent (Fig. 377), whilst the lower lip is enlarged and overhanging. The orbital ridges project, and the forehead is usually low; the nose and tip of the tongue are also more or less enlarged. The spine is kyphotic in the dorsal region, with a slight

lumbar lordosis. The ribs and sternum project anteriorly.

The patient usually suffers from headache, lassitude, and great fatigue, wandering pains about the body, and excessive appetite and thirst; amenorrhœa is a marked symptom in women, whilst men suffer from a loss of virile power. The urine is abundant, but of a low specific gravity. Vision is usually diminished, and optic neuritis has been observed in some cases.

Morbid Anatomy.—The cause of acromegaly appears to be overgrowth of the *anterior half of the pituitary* body, and excessive absorption of its secretion (hyper-pituitarism). The sella turcica is expanded, and this can be recognized by X-rays. The changes in the bones are merely those of overgrowth.

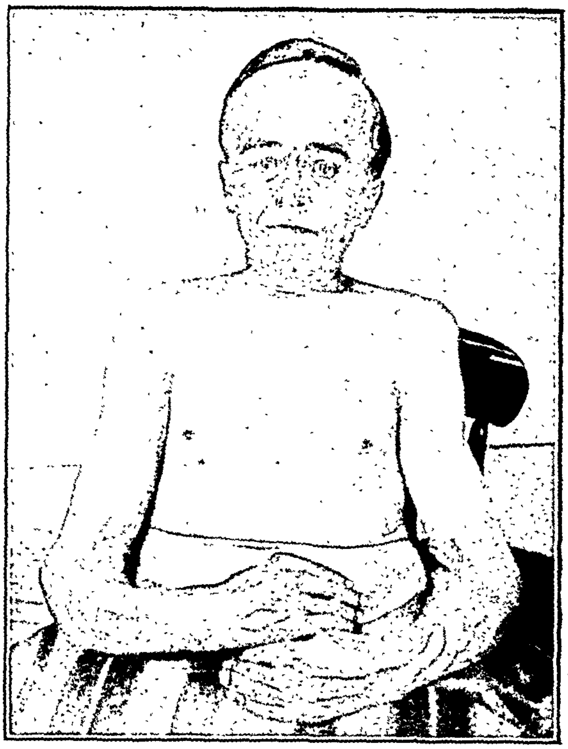


FIG. 376.—OSTEITIS DEFORMANS IN LATE STAGE.

Note size of the skull and curvature of humerus and of bones of forearms.

FIG. 377.—A MAN, ÆT. 28, WITH WELL-MARKED ACROMEGALY.

Note the great enlargement of the lower jaw and the left external squint.

Diagnosis.—The disease has been mistaken for *myxœdema*, but there is not much difficulty in distinguishing the two if it be remembered that, in the latter condition, the skin is not mobile over the thickened subcutaneous tissue; that the face is broad, pasty, and puffy; and that masses of gelatinous tissue are found above the clavicle; whilst in acromegaly the face is elongated and the skin and subcutaneous tissues normal. The mental condition and speech of a patient suffering from myxœdema are

widely different from those in acromegaly; whilst in the former the thyroid body is either absent or diseased, and in the latter skeletal changes are present. From *chronic osteoarthritis* affecting the hands the diagnosis is easy, in that there are usually no signs of articular disease, and much less pain. From *osteitis deformans* the distinguishing features have already been indicated.

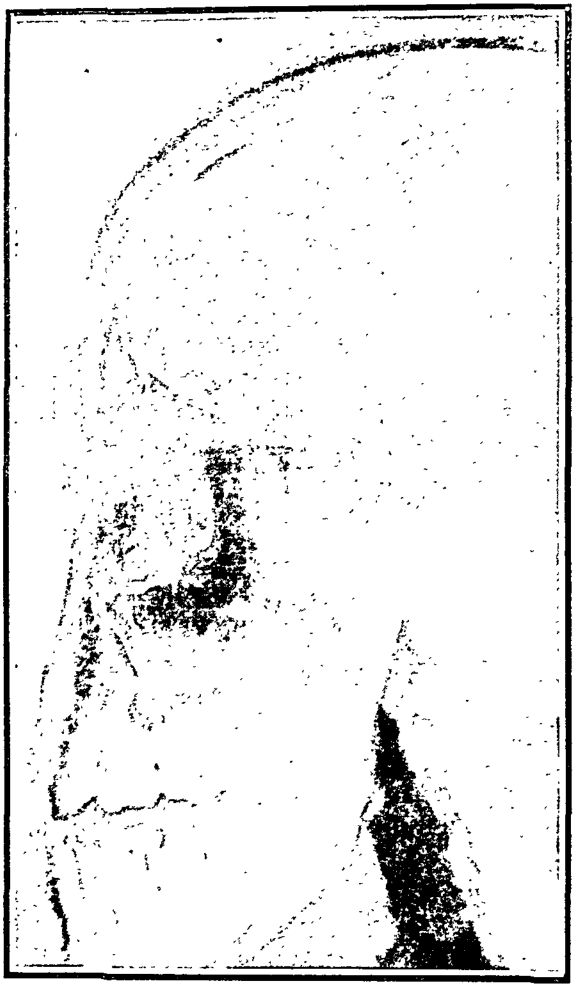


FIG. 378.—SKIAGRAM OF SKULL OF ACROMEGALIC PATIENT, SHOWING POSITION OF RADON SEEDS WHICH WERE INSERTED INTO THE PITUITARY BODY THROUGH AN OSTEOPLASTIC FRONTAL FLAP.

Treatment is merely symptomatic, antipyrin being useful in relieving the headache, as also valerianate of caffeine. Possibly thyroid extract may be of some use in combating the functional phenomena, though it will not influence the skeletal changes. Attempts have been made to remove the growth by operation with success.

In some cases, where increased intracranial pressure is observed, the introduction of radon seeds into the pituitary through a frontal osteoplastic approach may be very beneficial (Fig. 378).

In advanced acromegalics the lower jaw may be so enlarged that the patients' bite may be well out of alinement (Fig. 379). In these cases a wedge-shaped resection of the middle of the lower jaw should be performed on both sides, and gives excellent results. The idea that fracture through the jaw of an acromegalic never unites is mythical.

Hypertrophic Osteo-Arthropathy.—It has long been known that clubbing of the terminal phalanges is associated with chronic pulmonary and cardiac disease (Fig. 381); and it is probable that such is the earliest stage of this more generalized affection, first described by Pierre Marie. In it the ends of the fingers and toes are enlarged and bulbous, with the nails curved over towards the palm or sole; in the early stages the change may be limited to the soft tissues, but radio-

graphy has demonstrated that in the later there is a well-marked new formation of bone along the shafts of the phlaanges, and also of

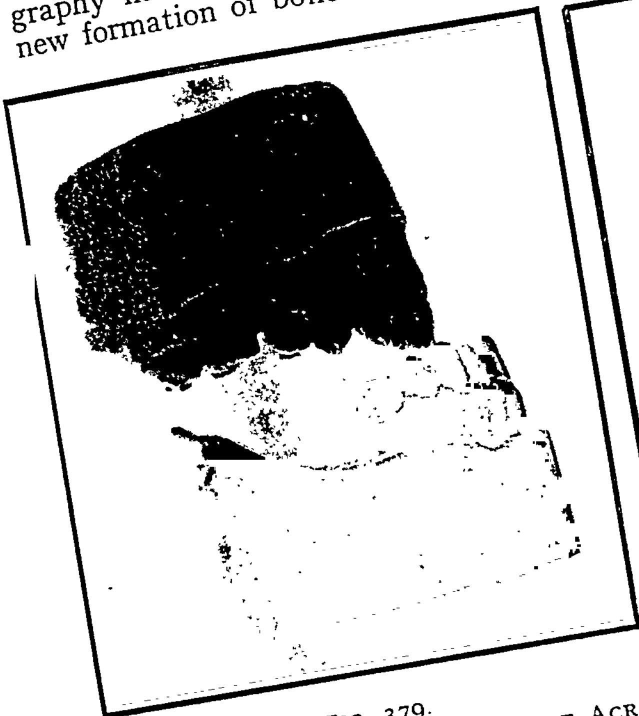


FIG. 379.

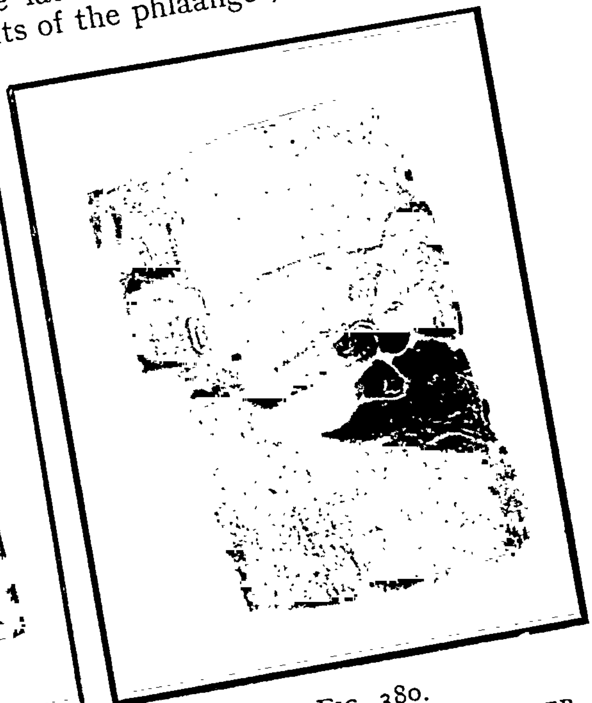


FIG. 380.

FIGS. 379 AND 380.—THE BITE OF ACROMEGALIC PATIENT BEFORE AND AFTER A WEDGE RESECTION OF THE HORIZONTAL RAMUS OF THE LOWER JAW.

the metatarsal and metacarpal bones. There is a considerable swelling of the bones just above the wrists and ankles, extending some way

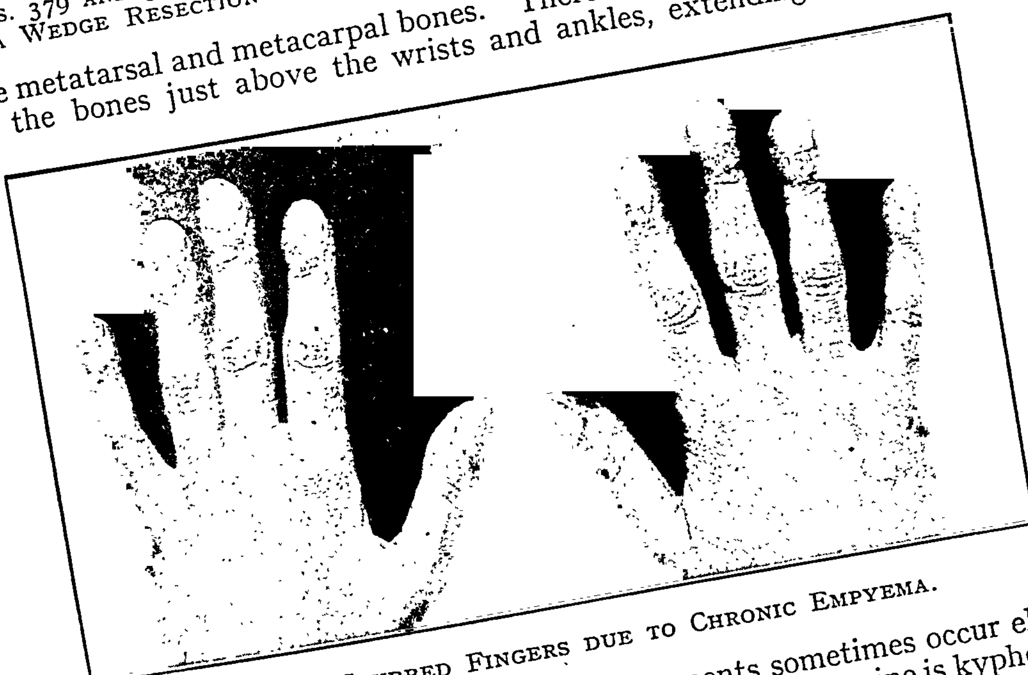


FIG. 381.—CLUBBED FINGERS DUE TO CHRONIC EMPYEMA.

along the shafts, and similar bony enlargements sometimes occur elsewhere; they are due to a diffuse osteo-periostitis. The spine is kyphotic

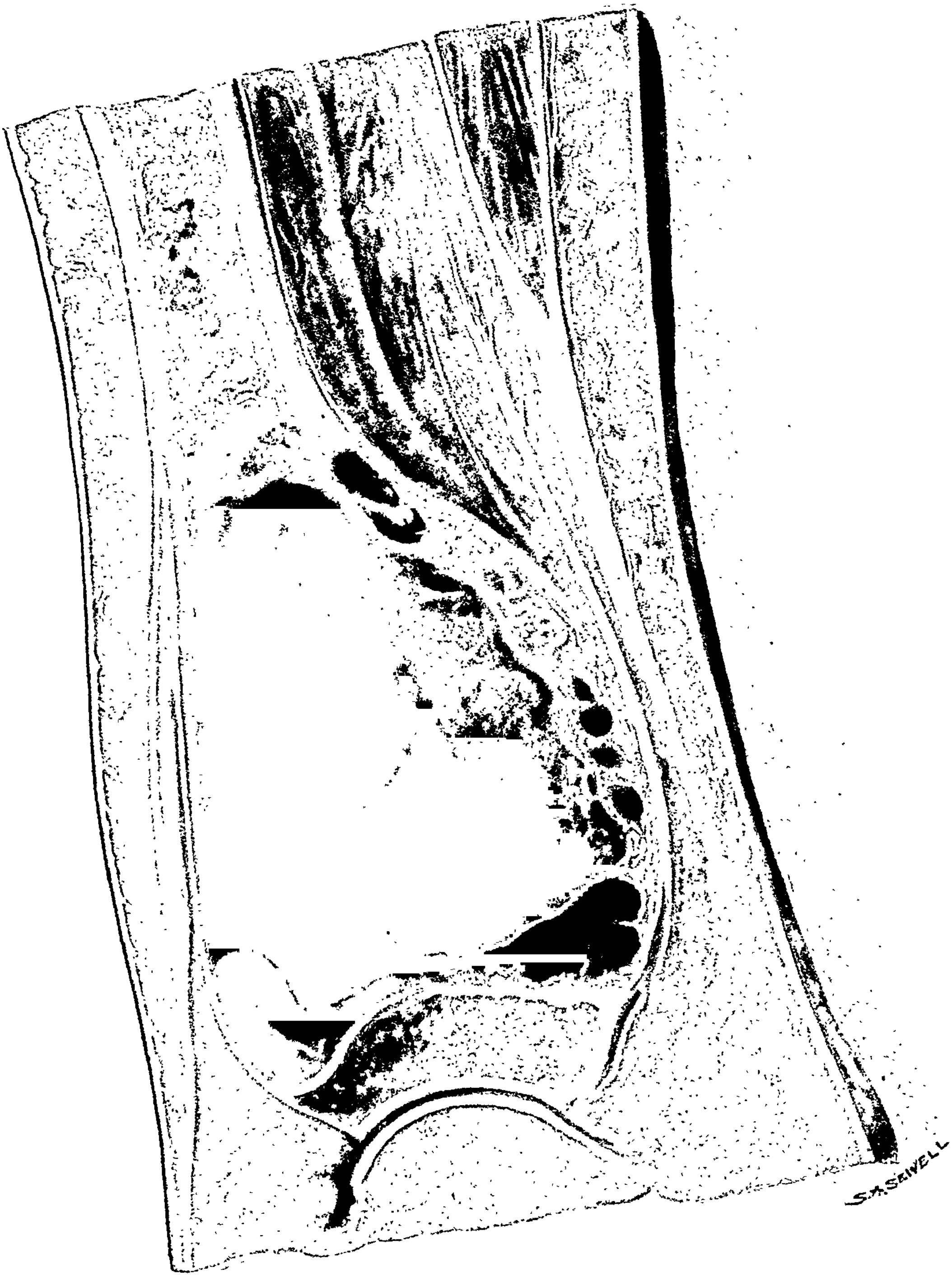
in the upper dorsal region, but with well-marked lordosis below. It is thus seen that the changes are somewhat like those of acromegaly, from which they are distinguished by (*a*) the implication chiefly of the fingers and toes, and particularly of the terminal phalanges, whilst in acromegaly the enlargement of the different portions of the hands and feet is general; (*b*) the nails are not affected in acromegaly; (*c*) the joints are but little involved in acromegaly; and (*d*) the enlargements of face, tongue, jaw, etc., so marked in acromegaly, are absent in osteo-arthropathy. These phenomena probably result from chronic toxic absorption, since the condition arises in such diseases as chronic bronchitis, bronchiectasis, and chronic empyema, where suppuration has existed for some time. It is, however, sometimes associated with lesions other than pulmonary, *e.g.* chronic jaundice, syphilis, and influenza, and has even been found in otherwise apparently healthy individuals. Little can be done in the way of treatment, except to deal with the cause, if obvious.

Tumours of Bone.

The characters of the osteomata, chrondromata, and fibromata of bone have been described in Chapter VII., and various solid and cystic tumours connected with the teeth are dealt with elsewhere.

Myeloma (Osteoclastoma or Giant-Cell Tumour) (Fig. 382 and Plate VIII.) is practically a benign tumour, rarely giving rise to secondary deposits either in lymphatic glands or viscera, and its growth within the bone is strictly limited, with no tendency to diffusion along the medulla; occasionally a layer of condensed bone demonstrable by radiography forms an effective barrier in this direction. It most commonly affects persons between twenty and forty years of age. For its pathological features (Fig. 383), see p. 201. The sites of election for myeloid tumours are the growing ends of the long bones, especially the lower ends of the femur and radius, and the upper ends of the humerus, tibia, and fibula, whilst they also occur in the diploë and lower jaw, and constitute one form of epulis. The development of the tumour leads to the so-called *expansion* of the bone, in which the osseous tissue is absorbed from the inner aspect, and new bone is laid down externally; the outer layers, however, gradually become thinned, so that after a time the osseous lamina can be pressed inwards, giving rise to a feeling known as 'eggshell crackling'; and finally the tumour projects through the bony wall. This expansion may be central, and the bone end thus becomes more or less globular, or it may be eccentric, and then the growth projects merely on one side. Sooner or later spontaneous fracture is likely to occur. Neighbouring joints usually escape, but in old-standing cases the growth may project around the articular cartilage and somewhat impair the movements; there may, however, be some serous effusion in the cavity. The **Symptoms** may be so slight at the commencement that nothing is noted until fracture has taken place; but sometimes pain similar to that of a chronic osteoperiostitis draws attention to the enlargement of the bone. Radiographic examination reveals a well-defined area of bone, which is

PLATE VIII



Osteoclastoma of the lower end of the Tibia
(*Museum, Royal College of Surgeons*)

[*To face page* 676

unduly translucent, but with the characteristic 'stippling' due to the presence of calcareous foci scattered through the growth. The

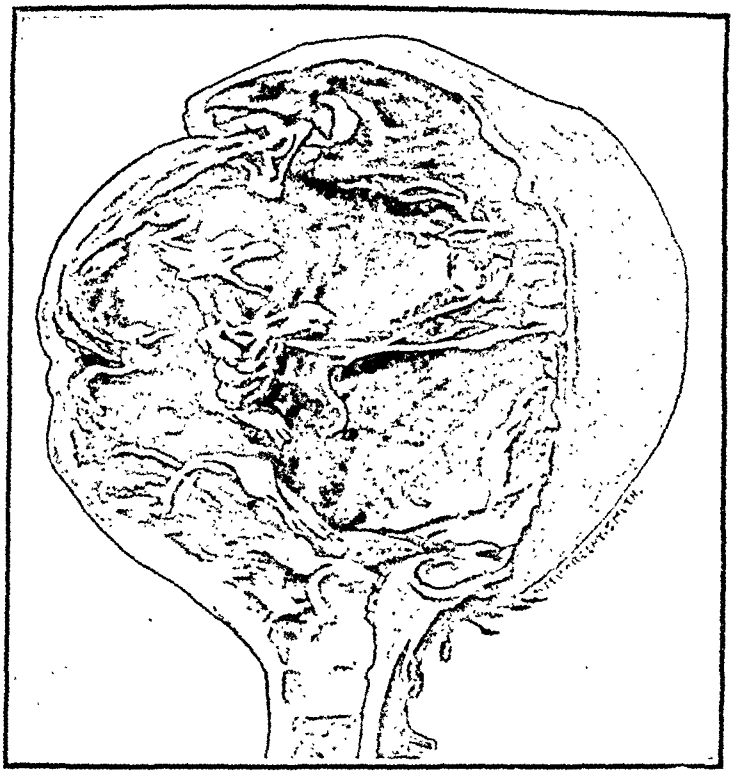


FIG. 382.—MYELOMA (OSTEOCLASTOMA) OF HEAD OF TIBIA

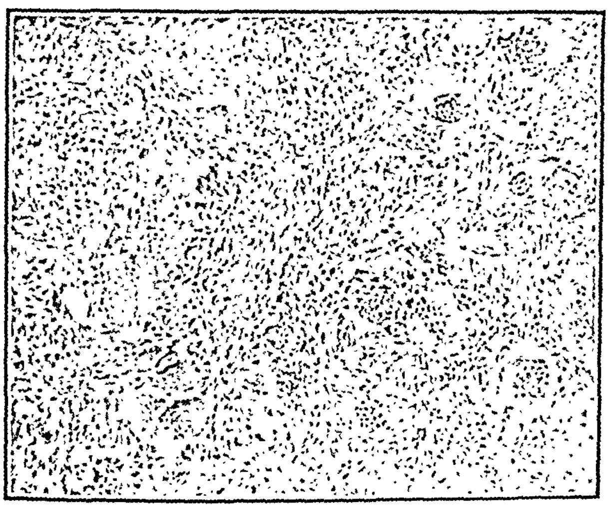


FIG. 383.—MICROPHOTOGRAPH OF A SECTION OF AN OSTEOCLASTOMA OF THE RADIUS.
The giant cells can be easily seen.

accurate limitation of the growth, and its demarcation from the medullary cavity, are important diagnostic signs.

Treatment is governed by the assurance that a myeloma is non-malignant, and hence may be dealt with in a conservative manner

FIG. 384.—MYELOMA OF LOWER END OF THE RADIUS.

FIG. 385.—THE SAME CASE AS FIG. 384 AFTER CURETTING AND THE INTRODUCTION OF BONE CHIPS.

FIG. 386.—MULTIPLE MYELOMATOSIS OF THE SKULL.

by a localized removal of the growth, amputation being reserved for the more advanced cases and for those where a local removal would

leave a more or less useless limb. In quite the early stages it suffices cleanly to excise the growth, or if that is impracticable, to incise and scrape it away with a sharp spoon, closing the wound without drainage, possibly after filling it with bone chips (Figs. 384 and 385). Subsequent exposure of the part to radium or X-rays is desirable in order to complete the destruction of the growth. In a later stage the affected portion of the bone may be completely removed, and if necessary the gap bridged by bone-grafting. Thus a myeloid tumour of the upper end of the fibula can be excised, care being taken of the external popliteal nerve and its branches; but if the upper end of the tibia or lower end of the femur is involved to the extent of destroying most of the bony substance, amputation may be required.

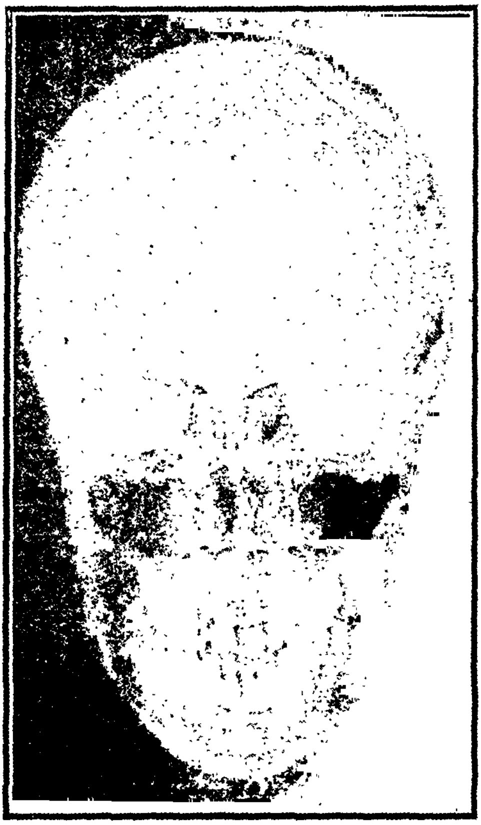


FIG. 387.—MULTIPLE MYELOMATOSIS OF THE SKULL.

Multiple Myelomatosis.—This is a somewhat rare condition, occurring usually between the ages of forty and sixty, and may be classified as a primary malignant tumour of the bone-marrow. It originates particularly in the bones which normally contain red marrow, and so is most frequently found in the vertebræ, sternum, and the ribs. The pelvic bones and the skull, however, are not uncommonly affected. The multiple tumours are independent growths, commencing simultaneously in a number of different bones, and begin as small nodules which vary in size from that of a pea to that of a hen's egg. The bone is gradually destroyed, and its place is taken by a soft greyish-red mass. The cells composing this mass consist of primitive types arising from the same cells as those found in the blood. In some cases the cells of this disease resemble plasma cells, and in the very rare examples where a single focus of this disease has been recorded without any disease whatever of other bones, it is this cell type that has been present. In the skull (Figs. 386 and 387) the growths appear as multiple clear areas of varying size. The disease first manifests itself by pain, and men are more often affected than women. The pain, usually in the back, becomes persistent, and kyphosis may develop and slight fever may occur. Bence-Jones proteosuria may be present. Secondary anæmia soon appears, and the patient dies of general cachexia with secondary metastatic deposits scattered throughout

the viscera. The actual diagnosis is confirmed by the X-ray appearances in the bones.

Treatment in the past was regarded as useless, but with modern deep X-ray therapy better results are being obtained.

Sarcoma of Bone.—It has been customary in the past to describe types of sarcoma of bone as endosteal or periosteal, according to which part of the bone development primarily arises. Other types described were based on the predominant groundwork of the tumour, so that such types as osteo-sarcoma, chondro-sarcoma, myxo-sarcoma,

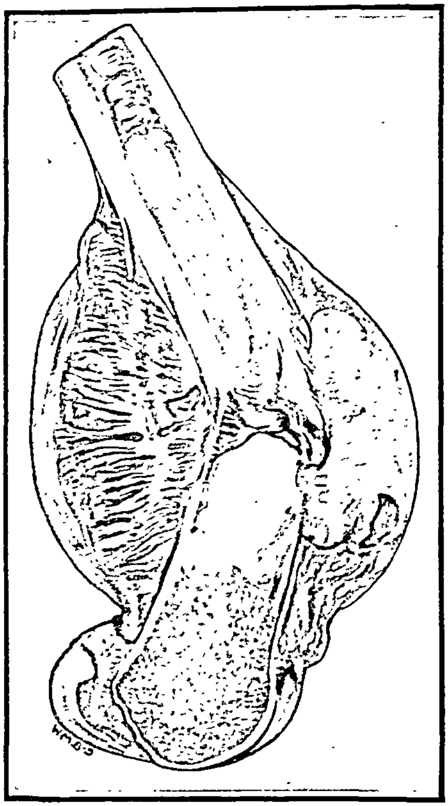


FIG. 388.—OSTEOGENIC SARCOMA DISSEMINATING ITSELF IN THE MEDULLARY CAVITY AND CAUSING A FRACTURE. (KING'S COLLEGE HOSPITAL MUSEUM.)

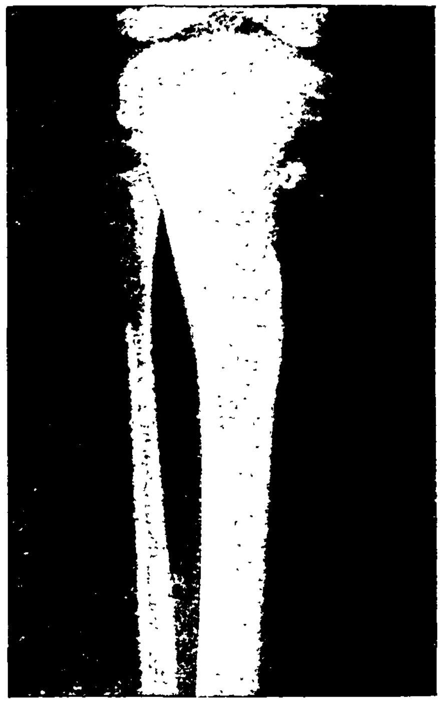


FIG. 389.—SARCOMA OF TIBIA OF THE OSTEOLYTIC TYPE.

fibro-sarcoma of bone were all mentioned. Such a classification is now regarded as false, because in most cases it is impossible to tell exactly in what part of the bone the tumour arose, as all parts are equally invaded, and even though one may have arisen from the cancellous and another from the compact bone the ultimate picture is alike and indistinguishable. Moreover, according to the various degenerations and changes that the matrix of the tumour undergoes so the differences, erroneously referred to as different types in the older classification, arise. It is better to refer to these sarcomas of bone as *osteogenic*

sarcomas, implying not that bone formation is an essential character, but that they arise from cells capable of forming bone. One type of sarcoma must, however, be clearly separated from this group, and that is a simple *fibro-sarcoma* arising from the fibrous tissue layers of the periosteum, a tumour related only to bone by virtue of its position. Any rarefaction of the shaft occurs by virtue of pressure or secondary involvement, and any periosteal reaction occurs as a result of irrita-

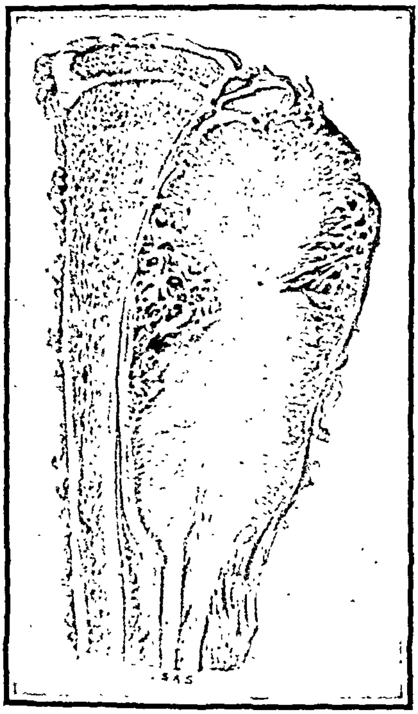


FIG. 390.—OSTEOGENIC SARCOMA OF FIBULA. (KING'S COLLEGE HOSPITAL MUSEUM.)

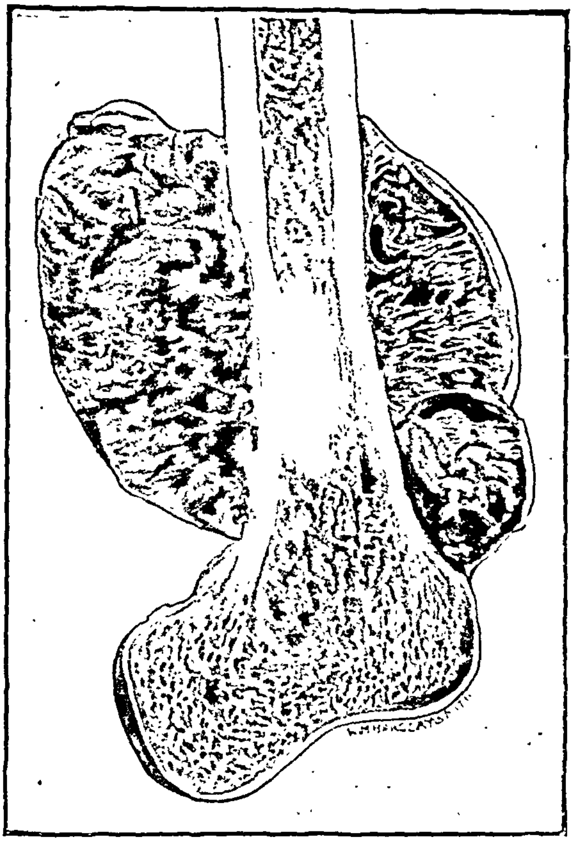


FIG. 391.—OSTEOGENIC SARCOMA OF LOWER END OF FEMUR ERODING BONE. (KING'S COLLEGE HOSPITAL MUSEUM.)

tion of the periosteum by fibro-sarcoma, not because the tumour is osteogenic.

The disease is one that affects most commonly adolescents of about fifteen years. It occurs in the metaphyseal region, the bones most commonly affected being the adjacent ends of the femur and tibia, the upper end of the humerus, and most rarely the radius, ulna, or scapula (Figs. 388, 389, 390, 391). Pathologically there is an invasion of all layers of the bone by the growth, the epiphyseal cartilage, however, and the periosteum to a lesser extent serving as barriers to the extension of the neoplasm. The tumour mass is richly supplied with blood-vessels, and hæmorrhage may occur into its substance with the formation of hæmorrhagic cysts. Sometimes the vascular supply is so abundant that pulsation occurs, giving rise to the so-

called 'malignant bone aneurism' (Fig. 392). In other cases the tumour is relatively avascular. The characteristic cell type of the tumour is usually a spindle-shaped cell, though round cells with hyperchromatic nuclei, and, in areas where much bone destruction is occurring, multinucleate osteoclasts, are common. The matrix, as we have seen, varies from tumour to tumour and may be osteoid, cartilaginous, fibrous, or myxomatous. At first the periosteum is merely raised up from the bone by the expanding tumour, but eventually this gives way and rapid permeation of the superficial tissues then occurs. At the junction of the raised with the normal periosteum radially placed striæ of ossification often form (Figs. 390 and 392), which are easily recognizable with the X-rays (Fig. 393). The tumour spreads partly by lymphatic invasion, but more extensively through emboli which become detached from areas of the growth invading the blood-vessels. Secondary deposits in the lungs should therefore be looked for in every case. The patient usually gives a history of relevant trauma some months or so before the onset of pain in the affected area, and this may be of especial severity at night and bring the patient to the doctor. If this is tolerated, the presence of a slowly growing tumour or even a fracture may send the patient for advice. In the early stages of the disease the patient's general health is good, but later anæmia and cachexia rapidly set in. Inquiry must always be made for chest complaints suggestive of secondary deposits, and it is important that an X-ray of the chest should be taken. On examination of the limb a deep swelling will be found with little evidence of increased heat or redness in the skin. There will probably be muscle wasting of some degree, but movements of the adjacent joints will be free. In the late stages the soft parts will be involved and the growth will ulcerate through the skin. X-ray examination will show an area of bone involvement with generalized absorption of the metaphysis, with perhaps little new bone formation. So great may the bone absorption be in the *osteolytic* type of sarcoma that re-

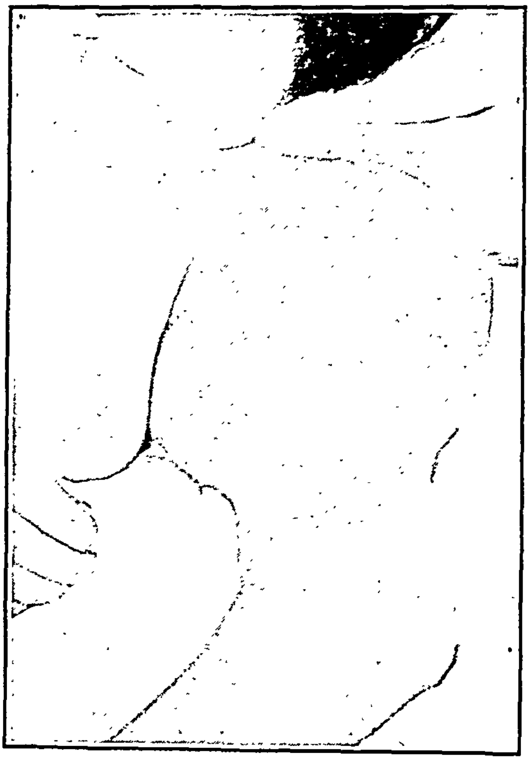


FIG. 392.—LARGE OSTEOGENIC SARCOMA OF HUMERUS: THE TUMOUR WAS SO VASCULAR THAT IT PULSATED. (MR. ROBERT MILNE'S CASE.)

semblance to a cyst is at first sight great, but the irregularity of the extension serves as a differentiating point. The prognosis in these cases is bad. Where doubt exists as to the diagnosis biopsy may be justified following a preliminary course of deep X-ray therapy.

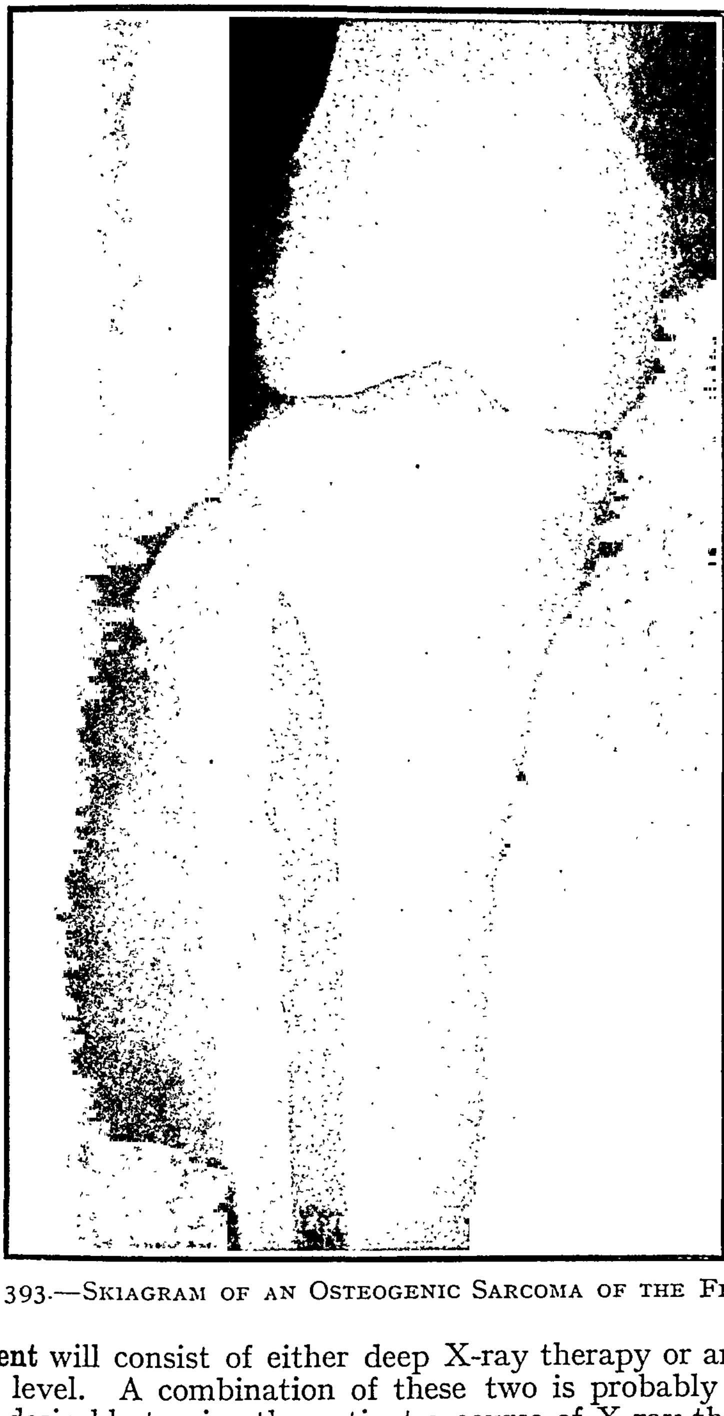


FIG. 393.—SKIAGRAM OF AN OSTEOGENIC SARCOMA OF THE FIBULA.

Treatment will consist of either deep X-ray therapy or amputation at a high level. A combination of these two is probably best, and it is most desirable to give the patient a course of X-ray therapy and follow this by an amputation. X-ray treatment alone often causes

a disappearance of the tumour, but recurrence is the rule, and these recurrences are resistant to further treatment.

Ewing's Tumour or Sarcoma is a rare tumour affecting the shaft of the long bones, more especially the tibia and the humerus, and giving rise to metastatic secondary deposits in other bones. It usually affects young adults and adolescents, who give a history of preceding trauma associated with some pain. This is followed by the appearance of a swelling which seems to undergo periodic variations in size, which are paralleled by leucocytosis, fever, general malaise, and perhaps redness and heat over the site of the tumour. These signs and symptoms may easily lead to the erroneous diagnosis of subacute osteo-myelitis. As in osteogenic sarcoma, during the early months of the disease the patient is generally fit and well, but with the onset of secondary deposits in the ribs, sternum, vertebræ, and other bones, anæmia, cachexia, and intolerable pain rapidly drag the patient downhill. The tumour consists of masses of round cells with very little intercellular matrix. Giant cells are never present. There is a general lysis of the bone affected, although the raised periosteum attempts to form lamellæ in the line of the original shaft. To the naked eye the tumour has an appearance suggestive of that associated with a subacute pyogenic condition in bone, which further serves to account for mistaken diagnosis in the past. The condition is probably less lethal than that of osteogenic sarcoma, but the treatment is identical.

Secondary Sarcoma of bone is by no means uncommon. It is almost always endosteal in character, and, except in the most unusual circumstances, will not demand treatment, owing to the general infection of the system. Possibly where it has led to spontaneous fracture, and there is much pain owing to the difficulty of fixation, it would be justifiable to remove the limb.

Carcinoma of bone is always secondary in nature, although it may be involved by direct extension in a primary growth. Secondary growths are endosteal in character, and often extremely painful; they may occasionally lead to spontaneous fracture, but the bone may consolidate again satisfactorily. After scirrhus mammæ, the bones of the chest wall, the upper end of the femur and vertebræ are those most often affected.

Pulsating Tumours of Bone, or Osteo-Aneurism.—Apart from pulsating sarcoma, two other conditions are met with in which distinct pulsation is also noticeable. In the first of these the medullary cavity is occupied by a non-malignant vascular tissue, practically identical with what has been already described as an *aneurism by anastomosis* (p. 369). These tumours are situated most frequently in the cranial bones, and may be multiple, the medullary tissue being in consequence atrophied, and the compact tissue thinned, so that 'eggshell crackling' may be obtained. The second form is found most commonly in the upper end of the tibia, or some such cancellous mass. It consists of a hollow cavity filled with blood. Several distinct arterial twigs may open into it, and the overlying bone is thinned and absorbed. It is probable that the majority of such cases are in reality due to the breaking down of a sarcoma of extreme tenuity, or possibly of a mye-

loma. **Treatment.**—If it seems probable that the condition is not associated with malignant disease, the cavity should be incised, scraped, swabbed out with pure carbolic acid, and then packed with a muscle graft, or with gauze, so as to obtain healing by granulation. If the bleeding persists, amputation is the only treatment.

Hydatid Disease of Bone.—The cancellous tissue of bones occasionally becomes the site of hydatid development, any part either of the medullary cavity or of the ends being involved. The bone becomes expanded, with all the symptoms of an endosteal growth. Considerable deformity may occur, and when the compact layer has been sufficiently absorbed, spontaneous fracture may follow. In this affection there is no limiting wall, the small daughter cysts being diffused through the affected area. Radiography and laboratory tests (p. 232) should suffice to ensure a diagnosis, but in countries where hydatid disease is rare, the condition is very liable not to be recognized until an exploratory incision has been made. **Treatment.**—If all the cysts can be removed without interfering with the integrity of the shaft, a recovery, with good subsequent utility of the limb, should follow. Where, however, the disease has encroached widely on the bony tissue, whether spontaneous fracture has occurred or not, amputation holds out the only prospect of cure, unless bone-grafting is feasible.

Affections of the Ribs and Sternum.

Osteomyelitis of the ribs is very unusual. Occasionally an acute pyococcal variety, running its usual course to necrosis, occurs in children; but the most common cause is typhoid fever (p. 651). The affection is then generally of a subacute type, and a more or less extensive cario-necrosis results. A special feature is the tendency of the bacilli to remain in a latent condition in the tissues, so that to ensure a perfect cure complete extirpation of the affected portion of bone is required.

Syphilitic Disease is more common in the sternum than in the ribs. The upper part of the *sternum* is usually involved, and the affection is characterized by a formation of gummata in and upon the bone, which erode it, usually in a pitted fashion, and may cause necrosis. Treatment with iodide of potassium and mercury is required, and sequestra must be removed. In connection with the *ribs*, syphilis appears as a tertiary periostitis or perichondritis. A fusiform swelling develops with but little pain or tenderness; it may easily be mistaken for tuberculous disease or a new growth, but the history may help to a correct diagnosis, which can be confirmed by the Wassermann test.

Tuberculous Disease affects the ribs much more frequently than the sternum. In the *ribs*, it may arise primarily as an osteomyelitis implicating an extensive portion of the medulla; but it is not unfrequently secondary to tubercle of neighbouring parts, *e.g.* the spine or pleura, and then commences beneath the periosteum; several ribs may be involved at the same time. The disease is most commonly seen in young people, and affects either the middle of the rib or the

costo-chondral junction. The usual manifestations of tubercle in bone are seen, giving rise to expansion of the bone, or to caries or necrosis, and suppuration is common. The abscess cavity may be mainly external to the ribs, but is not unfrequently hour-glass-shaped, a narrow neck connecting the cavities which lie inside and outside the chest. *Treatment* in these cases may have to be of a radical type, including complete removal of an extensive portion of the rib and of the abscess cavity attached to it.

In the *sternum* tubercle runs its ordinary course, and may present an abscess which points either in front near the middle line, or may come forwards from behind through an intercostal space. Treatment is of the usual sanatorium type, but if an abscess needs to be opened, the opportunity should be taken of curetting the bone.

Tumours of the ribs and sternum are usually chondromata or chondro-sarcomata; perhaps the former are a little more common in the ribs, the latter in the sternum. The patient complains of but little pain, and therefore the cases are usually late in coming under observation. In time the growth becomes adherent to the pleura, and the lung itself may be invaded. In the early stages it is sometimes possible to remove them, although the lung is liable to collapse unless special precautions are taken.

Bone-grafting is an operation which has come much to the front of late, and is required for many ununited fractures, especially where there has been great loss of tissue, as also for reparative purposes where much bone has been removed with tumours or cysts. It is also employed for purposes of fixation of joints or of the spine.

Formerly fragments of dead bone, or rods of ivory, were employed, but, of course, they are merely passive actors in the process of regeneration, being absorbed or replaced. Living bone, on the contrary, is capable of retaining its vitality, and uniting with the surrounding parts, even if totally separated from its former osseous connections. The graft must be obtained from the patient himself (*autogenous*), those from another patient (*homogenous*) or from a freshly killed animal (*heterogenous*) being unsatisfactory as they do not survive the transplant.

The persisting capacity of bone cells to reproduce osseous tissue away from their old surroundings is the basis on which the success of bone-grafting depends. Unfortunately, this capacity is not always exercised in the direction the surgeon desires; thus new bone may form where it is not wanted, *e.g.* in cases of traumatic myositis ossificans; and it may fail to develop where most needed, as after fractures or bone-grafting. Sometimes a graft is absorbed completely after an apparently successful operation, and non-union follows. It is clear, therefore, that there are still some points in this procedure which are not fully understood.

Many methods of grafting have been employed from time to time, varying with the different ideas as to the destiny and usefulness of grafts, and with the manipulative dexterity and mechanical appliances at the disposal of the particular surgeon.

1. It is possible to utilize chipped-up fragments of living bone, either loosely powdered in the cavity to be filled, or firmly packed in. These may easily be procured from the subperiosteal surface of the tibia. It is probably best to pack the cavity firmly and close it entirely; the grafts survive on account of the blood-plasma permeating through the cavity until the time arrives when the whole mass is vascularized and organized. An ununited fracture may be treated in this way by freeing the ends, and making a fresh section of them to expose healthy bone tissue; they are then fixed, *e.g.* by a plate, and the interval between the fragments packed firmly with bone chips. This is not, however, a procedure to be recommended if other means are available.

2. In some situations all that is required is a thin lamella of bony tissue, *e.g.* in cranioplasty, or in some ununited fractures of the lower jaw. A suitable shaped flap is marked out on the front of the tibia or crest of the ilium, and the superficial layer of bone, together with the periosteum, is chiselled up and transplanted. In some fractures of the jaw a thin graft such as that described may be rolled up like a cigarette and fixed between the bone ends.

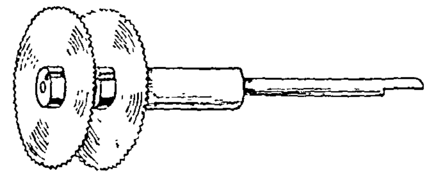


FIG. 394.—DOUBLE CIRCULAR SAW FOR BONE-GRAFTING (ALBEE). The distance between the two saws is easily regulated.

3. In other places a more massive graft is desirable, and for this purpose complete sections of bones, *e.g.* of the fibula, or a metatarsal bone, were employed in the first place. They are effective, but not very suitable in all cases. Portions of ribs also have been used for reconstituting a lower jaw.

The introduction by Albee of the double circular saw (Fig. 394) driven by an electric motor has revolutionized this procedure, and placed in the hands of surgeons the means of cutting rapidly grafts which are well adapted for the part they have to play. The front of the tibia is the favourite site from which to obtain such grafts for work on the long bones.

Much discussion has arisen as to whether or not a bone-graft should include the periosteum, and as to its depth. There is no question that the retention of vitality of the graft depends upon its gaining a fresh blood-supply as rapidly as possible; failing this, the graft dies, and is absorbed or cast out of the body. To establish vascular continuity between the graft and the tissues in which it is placed must obviously be easier if it is covered with fibrous tissue which is vascular under normal conditions, or leaves an exposed surface of cancellous bone. Hence, whenever practicable, it is desirable that the graft should be covered with periosteum externally, and should include a portion of the vascular medullary tissue on its deeper aspect. Naturally the less the graft is handled the better, inasmuch as the superficial cells are thereby less likely to be killed.

It is hardly necessary to point out that for success the following essentials must be secured: (1) *Absolute asepsis.* This excludes early

operation on compound fractures, however desirable it may appear from the functional standpoint. Healing must have been secured for some time before bone-grafting is considered. (2) *Absolute hæmostasis* is necessary in order that the graft may unite rapidly with the surrounding tissues, and thus its vascular supply be ensured; the presence of a hæmatoma may jeopardize its vitality. (3) *Effective fixation* is most desirable, but if this can be secured without the use of nails, screws, or wires, so much the better; these all have a tendency to hinder reparative activity in their immediate neighbourhood; wires are less harmful than nails or screws. Autogenous bone nails or pegs are very useful, and may be cut by the shaper provided with the Albee saw outfit. (4) Complete rest must be provided after the operation,

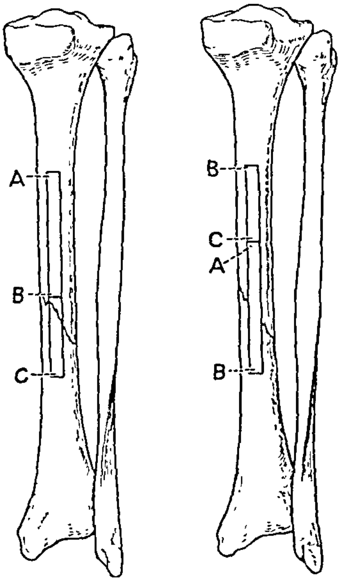


FIG. 395.—SLIDING INLAY BONE GRAFT.

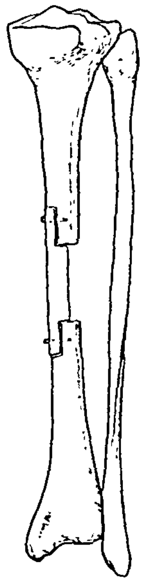


FIG. 396. — BONE-GRAFTING BY A 'STEPPED' LATERAL GRAFT.

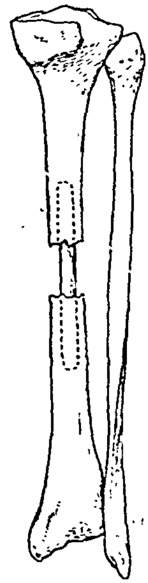


FIG. 397. — BONE-GRAFTING BY AN INTRAMEDULLARY PLUG.

so as to permit of effective healing between the bone and the graft; too early mobilization might break up this bond of union. (5) On the other hand, as soon as union is effective, active use of the limb is desirable in order to stimulate its growth, the amount and direction of which reacts to the strain and stress placed upon the part; in other words, growth and structure depend on function.

It is impossible here to enter into details as to the various operations which may be required. It must suffice to point out three of the different methods of bone graft suitable for lesions of the long bones; others will be hinted at elsewhere.

1. The **Sliding Inlay** (Fig. 395) is a most useful method for dealing with fractures which are difficult to retain in position, or for certain ununited fractures. It consists in cutting a long narrow graft extend-

ing over both fragments (AB and BC) in such a manner that the portion derived from one fragment is double the length of that from the other. They are detached from their deep connections, and the longer (AB) is slid down so as to lie across the line of fracture; the shorter (BC) is transferred to fill up the gap left by the displacement of AB. If the grafts go down to the medullary tissue they fit accurately, and no fixation wires or screws are necessary; the periosteum in such an operation is advisably stripped back, and replaced after the operation.

2. The **Lateral Graft** (Fig. 396) is employed more frequently where there is actual loss of substance. The parts are laid open; the ends of the bone are freed, and suitably ' stepped ' so as to receive the graft cut from the tibia. It is laid in position and fixed by wires or bone pegs or screws, and the soft tissues closed over it. A similar plan may be adopted for ununited fractures with no great loss of substance.

3. The **Intramedullary Plug** (Fig. 397) gives fairly accurate fixation, but, as already pointed out (p. 551), it is not an altogether desirable method of procedure. There is also a considerable liability to fracture of the graft if exposed to strain too early.

CHAPTER XXII.

INJURIES OF JOINTS—DISLOCATIONS.

Sprains or strains result from sudden violence applied to a joint either directly or indirectly, and consist in tearing or stretching of ligaments or tendinous insertions of muscles close to the articular lines; in not a few instances the synovial membrane is also involved. The accident itself is very painful, and is followed by heat and swelling of the joint, due to a hæmorrhagic effusion, which with care and rest disappears in a few days, and with suitable after-treatment the joint recovers perfectly; but in the absence of the latter, recurring attacks of pain and persistent weakness are likely to develop. A neglected sprain may originate tuberculous disease or osteo-arthritis. If the patient is in a bad state of health at the time of the injury, an attack of infective arthritis may be determined.

Careful palpation to discover the most tender spot indicates the situation of the lesion, which may be at the insertion of the muscle or ligament, or at any part of its course. **Treatment** consists in putting the part to rest and supporting it firmly by a bandage over cotton-wool so as to limit effusion and to bring the segments of the divided structure into close apposition; in the more severe cases a splint should be applied. At the end of a week or ten days the splint may be dispensed with, and support secured by strapping or an elastic bandage. Massage and the alternate application of hot and cold douches also assist in restoring the function of the part, but special care must be taken to prevent stretching or injury to the newly-formed bond of union.

Thus in a **sprained ankle** the lesion commonly involves one of the fasciculi of the external lateral ligament. To bring the damaged structures into apposition, the foot is everted, and bandages or strapping must be applied so as to maintain this position, and hence must pass across the sole of the foot from within outwards and upwards. When the patient begins to get about once again, this position must still be kept up by the use of a boot, the heels and sole of which are thickened slightly on the outer side. Similarly, if the internal lateral ligament is damaged, the foot must be kept in the varus position, and the sole and heel of the boot thickened by patches placed on the inner side.

A sprain of the **internal lateral ligament of the knee** causes tenderness over its attachment to the tibia (Fig. 415), and pain is specially elicited by eversion or abduction of the leg. The synovial effusion is treated in the usual way by rest in bed on a back splint, and when this has disappeared the joint must be strapped or firmly bandaged, and the weight diverted to the outer side of the limb by thickening the inner

aspect of the sole and heel of the boot. Massage will, of course, be helpful, but efficient support and protection from recurrence of the mischief are even more important.

Penetrating Wounds of Joints are often accompanied by an escape of synovia, which is recognized as a glairy, oily fluid, floating perhaps on the surface of the blood; if, however, the aperture is small, this may not occur. It is always followed by a certain amount of reaction, the character of which depends on whether or not the joint is infected. If no infection has taken place, a simple synovitis ensues, but soon passes; if, however, infection has occurred, suppurative synovitis probably supervenes, leading perhaps to acute arthritis and disorganization to the joint. A penetrating wound, even if untreated, does not necessarily become infected; thus, if the lesion is produced by a small, clean instrument, and especially if this is inserted in a slanting direction, so that the wound is valvular, or if the incision is a large one, allowing free vent to all discharges, recovery without infection is possible.

Treatment.—If the wound is small, and there is reason to believe that infection has not occurred, the external skin should be thoroughly purified, and an aseptic dressing applied, together with a suitable splint to keep the limb at rest. A careful watch is kept upon the temperature and pulse, and also on the condition of the joint, painful distension of which probably indicates infection. The synovial cavity is then at once aspirated with a syringe and its contents withdrawn and carefully examined. (1) If the fluid is quite clear and merely blood-stained, probably no serious mischief is present. (2) If it is slightly turbid, infection is present, and the joint should be washed out with sterile saline solution, and perhaps injected with 2 drachms of a 2 per cent. solution of formalin in glycerine, or with 2 to 4 drachms of a 1 in 1,000 solution of flavine. The limb is placed on a splint with slight extension and kept at rest; for a knee-joint, a Thomas's splint should be employed. Re-accumulation of the fluid necessitates a repetition of the same procedure every day or two. (3) If the fluid is from the first frankly purulent, or becomes so, a similar proceeding may be undertaken so long as the general and local symptoms are satisfactory and do not indicate any grave arthritic complications; but if the swelling of the limb increases, as also the pain and fever, then the treatment for acute arthritis must be instituted. (4) If the bacteriological examination reveals the presence of a hæmolyzing streptococcus, the chances of curing the trouble without ankylosis or amputation are much diminished.

Where the external wound is large, and probably infected from the first, its treatment must correspond to that of a gunshot wound, *viz.* it must be carefully excised down to the lesion in the synovial membrane. The margins of the rent in the membrane are cut away, and the joint cavity washed out with sterilized saline solution, followed perhaps by ether or by the 2 per cent. solution of formalin in glycerine. The cavity is now closed, a proceeding facilitated sometimes by loosening the suprapatellar pouch from the front of the femur, and the external wound sutured or packed with gauze impregnated with

flavine or 'bipp,' with a view to delayed primary suture in a day or two.

The after-treatment of these cases is as for those of suppurative lesions of joints generally (p. 732).

Dislocations.

A **Congenital Dislocation** is one due to some irregularity of location of the bony constituents of a joint present at birth, resulting from some error of development. The hip-joint is most frequently affected (p. 500). A **recurring** dislocation is one which develops again and again on the slightest provocation or follows any injudicious movement. It is generally due to some slight irregularity in the shape of the bone end, but also to capsular relaxation, largely induced by the frequently repeated attacks of synovitis following the displacement. The shoulder and temporo-maxillary joints are most often affected.

Pathological Dislocations are produced as the result of some intra-articular affection, *e.g.* tuberculous disease, osteo-arthritis, Charcot's disease, etc. It is unnecessary to describe them here.

Traumatic Dislocations.—The **Causes** are divided into predisposing and exciting. Under the former head may be included anatomical peculiarities, such as the shallow socket of the glenoid cavity, or some muscular or ligamentous weakness. Dislocations are rare in children since any violence directed to a joint or its neighbourhood is more likely to lead to an epiphyseal separation. Moreover, in old people the bones become brittle, and thus fractures, rather than dislocations, are produced; hence the latter lesions are almost limited to adults, and, owing to their greater exposure to injury, occur in men rather than in women.

The **Exciting Causes** are the application of external violence and muscular force, acting alone or in combination. The former may be direct, but is more commonly indirect, the force being applied at a distance from the joint. Muscular action by itself can only produce dislocation in certain joints; the head of the humerus, the patella and condyle of the jaw, are the bones most often affected in this way. If, however, the ligaments of a joint have been stretched by previous disease or displacement, recurrent dislocations from muscular action are not unusual.

The term *complete dislocation*, or *luxation*, is applied to that condition in which the articular surfaces of the bones are completely separated from one another. An *incomplete dislocation*, or *subluxation*, is one in which the surfaces are only partially separated.

An *open dislocation* is one in which the skin has been ruptured and communication established with the external air. A *complicated dislocation* is one in which there has been some associated injury of vessels, nerves, or viscera. The term *fracture-dislocation* is one applied to a condition in which a dislocation is complicated by fracture of one or both bones involved.

The **Signs** of a dislocation are as follows: (1) The evidences of a local trauma, *e.g.* pain, bruising, and swelling of the soft tissues, due

to their laceration and the effusion of blood into them; (2) deformity, due to the articular end of the displaced bone being in some abnormal position, where it can often be felt and sometimes seen; and (3) restricted mobility of the affected joint, and hence impairment of function. The degree to which this latter phenomenon obtains is necessarily variable, but as a rule it is very marked; if, however, fracture is also present, passive movements may be possible, though associated with pain and crepitus.

The **Effects** produced by a dislocation extend to all the structures entering into and surrounding the site of injury. The ligaments are partially or completely torn; the bony surfaces are not unfrequently fractured, especially in closely-fitting hinge-joints, such as the elbow and ankle; the cartilages may be bruised, or portions of them detached, and neighbouring muscles and tendons lacerated and displaced; adjacent vessels and nerves are often contused or compressed. Considerable effusion of blood is always present.

The character of the injury explains the difficulties that are met with in its reduction. (*a*) The anatomical arrangement of the joint and its ligaments results in the hitching of bony prominences against one another, whilst the head of the bone does not always lie opposite the hole in the capsule through which it originally passed. In a few cases the end of the bone may be grasped by neighbouring ligaments and tendons in such a way as to hinder its replacement. (*b*) Muscular contraction also constitutes an obstacle, which, though it can be counteracted by suitable traction, is more effectively overcome by the use of an anæsthetic. Not only does the patient maintain the limb in a condition of rest by a voluntary tonic contraction, but it becomes fixed by the involuntary passive tension of the displaced muscles.

When once reduced, there is usually but little tendency for a dislocation to occur. Reparative changes quickly manifest themselves; blood-clot is absorbed; the rent in the capsule closes by cicatrization, and in many cases no permanent lesion remains; in some, however, the joint is left in a weak and relaxed state, and liable to a recurrence of the displacement, while intra-articular adhesions, or the cicatricial contraction of the injured ligaments and muscles, may cause some loss of mobility.

If a dislocation is *allowed to remain unreduced*, the true articular cavity becomes shallow and partly filled up by a transformation of its cartilage into fibrous tissue, whilst the displaced head of the bone becomes adherent to the structures amongst which it lies; as the result of a plastic inflammation, either dense fibrous adhesions are formed, or a new false joint (*pseudarthrosis*). The articular cartilage is eroded, and the exposed bone eburnated and sclerosed, whilst, owing to chronic periostitis, the end of the shaft may be considerably deformed. The portion of bone upon which the displaced head rests undergoes changes, partly atrophic (from pressure), partly hypertrophic (as a result of chronic periostitis), whereby a new socket is produced (Fig. 398). Neighbouring muscles are secondarily shortened, and accommodate themselves to the abnormal position of the limb, and tendons which have been torn gain fresh attachments. These

changes necessarily interfere more or less seriously with the power of the limb and the movements of the joint. Serious pain is not unfrequently caused by pressure on neighbouring nerves.

Treatment.—The displaced bone should be reduced with as little delay as possible, and to effect this two chief methods are employed, *viz.* manipulation and extension.

Manipulation should always be used when practicable, less injury being sustained by the surrounding tissues. It consists in moving the

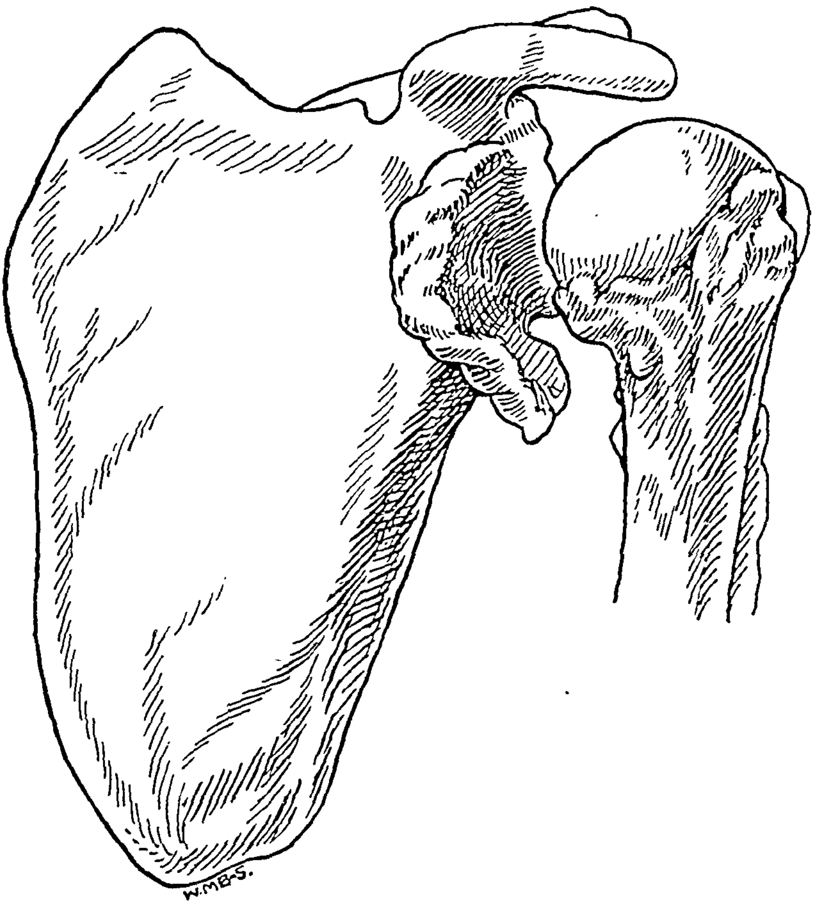


FIG. 398.—OLD-STANDING SUBCORACOID DISLOCATION OF THE SHOULDER, SHOWING ATROPHY OF TRUE GLENOID CAVITY, TOGETHER WITH FORMATION OF NEW JOINT AND ALTERATION IN SHAPE OF HEAD OF BONE. (FROM COLLEGE OF SURGEONS MUSEUM.)

limb in such directions as shall cause the displaced end to retrace the course that it has already taken, through the rent in the capsule to its normal position. The shoulder and hip joints are more amenable to this method of treatment than hinge joints. Anæsthesia will be required in difficult cases, and especially in dislocations of the shoulder and hip joints, but it is only right to draw attention to the fact that a large number of anæsthetic fatalities have been reported as occurring in the treatment of shoulder dislocations; this is due mainly to two

causes, *viz.* the deep anæsthesia required, and the want of preparation of the patient.

Extension is employed to overcome muscular and other forms of resistance, so as to allow the bone to slip back or be manipulated into its original position. In order to make this effectual, the parts above the dislocation are steadied by some *counter-extending* force applied either by the hands of an assistant, or by a belt or towel, or by the knee or foot of the surgeon. Extension may be made by the hands, or a firmer grip may be maintained, and greater force used, by applying a bandage or towel to the limb.

Reduction, however produced, is usually accompanied by a sudden and distinct snap or suction sound, due to the contraction of muscles, unless the patient is deeply under an anæsthetic, and the muscles are absolutely relaxed. The limb is subsequently kept at rest for some days, to allow the rent in the capsule to heal, but massage may be started in a day or two, and passive movements after a week.

The treatment of an unreduced dislocation is often a matter of considerable difficulty. Attempts at reduction *may* be undertaken up to two months, but the greatest caution must be employed for fear of rupturing adhesions and endangering the main vessels or nerves.

The amount of mobility in an unreduced dislocation varies much in different cases, and the character of the treatment is mainly governed by this. If movement is tolerably free, and not particularly painful, massage and manipulation may be undertaken and a very useful limb result. Where, however, movement is both painful and limited, operative treatment is desirable. (i.) Reduction by *open operation* consists in cutting down on the head of the bone, and freeing it from adhesions to surrounding structures, the capsule of the joint being also opened and the cavity cleared; reduction may then be possible by means of manipulation or extension. A few cases of successful treatment of old-standing dislocations of the shoulder by this means have been recorded; but as a rule the improvement is scarcely commensurate with the risks and difficulties of the operation, especially if a considerable interval has elapsed since the accident. (ii.) *Excision* of the displaced portion of the bone will often give a better result. In the elbow-joint it may be the only practicable treatment, and in the shoulder and hip it is usually better than attempting open reduction.

Open dislocations are always serious lesions, for not only are adjacent vessels and nerves liable to injury, but unless efficient treatment is adopted, suppurative arthritis ensues, leading to disorganization of the articulation, with subsequent ankylosis, or, in the case of larger joints, possibly to death from pyæmia or toxic poisoning. The **Treatment** consists in applying the principles already enunciated for those of all serious lacerated wounds (p. 239). The surrounding skin is first thoroughly purified; the edges of the external wound are excised, as also any gravely damaged soft tissues; the dislocation is reduced; the deeper parts are examined, and if need be washed with an antiseptic, or 'bipped,' and the whole wound closed with or without drainage, or temporarily packed with a view to performing delayed primary suture. The bone, if much damaged, must be dealt with according to the

instructions given for the treatment of open fractures, but immediate excision is probably desirable if retention of the damaged part is likely to be followed by ankylosis.

Special Dislocations.

Dislocation of the Lower Jaw forwards is not a very common accident, and usually results either from muscular action, or from a blow on the chin when the mouth is widely open, as in gaping, laughing, or attempting to take a large bite. It has also been produced in dentistry during tooth-drawing, or from digging out roots with an elevator.

The *mechanism* of the dislocation is as follows: When the mouth is opened, the condyle of the jaw slips forwards on to the eminentia articularis, and it requires very little force to displace it still further into the zygomatic fossa (Fig. 399). The interarticular cartilage follows the condyle, and the attachment of the external pterygoid muscle to that structure and to the bone explains the occurrence of dislocation from muscular action.

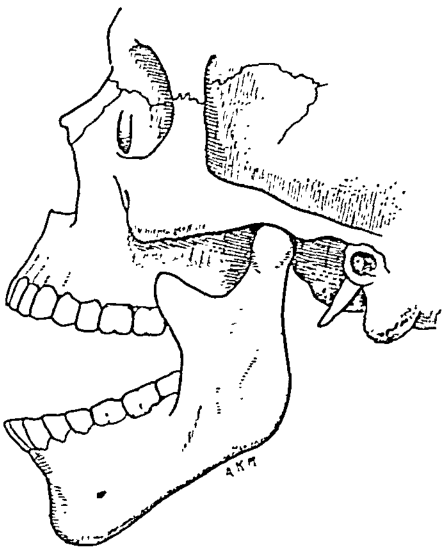


FIG. 399.—DISLOCATION OF JAW.

The displacement may be unilateral or bilateral—more frequently the latter. The mouth remains widely open, the teeth and the jaws being separated by an interval of about an inch. The lower jaw projects and is fixed, saliva dribbling over the lip; speech and deglutition are impaired, the pronunciation of the labial consonants being especially difficult. A hollow can be detected immediately in front of the tragus, where the condyle is normally lodged, and in front of this the condyle can be felt, being recognized by the slight amount of passive movement still possible. A finger in the mouth may define the coronoid process in an abnormal position beneath the zygoma.

Treatment.—Reduction is usually easy. All that is needed is to depress the condyle below the level of the eminentia articularis, when the masseter, temporal, and internal pterygoid muscles speedily draw it back into the glenoid cavity. The patient is seated in a chair; the surgeon standing in front protects his thumbs with thick napkins, and introduces them into the mouth, pressing upon the lower molar teeth. Pressure is continued in a downward and backward direction until the condyle is free, and then the chin is raised by the fingers on either side. The jaw is kept at rest for a week or ten days by means of a four-tailed bandage. Anæsthesia is occasionally necessary.

A few cases are on record of displacement of the condyle of the jaw *backwards*, associated with fracture of the tympanic plate and tearing or separation of the cartilage of the auricle, leading to bleeding from the ear. Displacement *upwards* into the cranial cavity through the roof of the glenoid fossa has also been described.

Subluxation of the Temporo-maxillary Joint is due to displacement of a relaxed interarticular cartilage, which becomes folded or nipped on opening the mouth, the result being a painful temporary fixation of the jaw, with a snap or crack on freeing it (*q.v.*).

Dislocation of the Sternal End of the Clavicle.—In spite of the apparent weakness of this joint and the great strains to which it is subjected, dislocation is uncommon, owing to the strength of the ligaments surrounding it, particularly of the rhomboid, the clavicle being more easily broken than displaced. The **cause** of these dislocations is always violence directed to the outer end of the bone, and since that usually acts from in front, the inner end of the bone is generally thrown forwards. Two other varieties are described, however, in which the displacement is backwards or upwards, but it is generally incomplete.

In the **forward** dislocation the end of the bone lies on the anterior surface of the manubrium, where it can be easily detected; all the ligaments of the joint are torn, except, perhaps, the interclavicular. The point of the shoulder is approximated to the middle line. **Treatment.**—Reduction is effected by placing the knee against the spine between the scapulæ, and drawing the shoulders backwards, the elbow on the affected side being kept in front of the mid-axillary line. To prevent recurrence, a pad of adhesive plaster, six or eight layers thick, and with the sticky side out, is carefully moulded over the end of the bone and fixed by other strips of plaster. The arm is then put up as for a fractured clavicle. No bad result follows, even if the dislocation remains partly unreduced.

The **backward** and **upward** dislocations are both extremely rare, and in each pressure symptoms on the trachea and great vessels of the neck may be produced. Reduction is effected as in the forward displacement, or by levering the inner end of the clavicle outwards by manipulating the arm over the surgeon's knee placed as a fulcrum on the axilla.

Dislocation of the Acromio-clavicular Joint consists in the acromion being forced either above or below the outer end of the clavicle, more commonly the latter. The displacement is easily recognized by the abnormal prominence of one or other of the bones. It usually results from violence directed to the scapula. No difficulty is experienced in reduction, but the displacement is very liable to recur, especially in the more common form. The elbow is then flexed to a right angle, and pads of several layers of adhesive plaster placed over the acromion and beneath the elbow; a bandage or strap, applied over the shoulder and under the elbow, suffices to maintain the bone in position. The strap is kept from slipping by passing a bandage under it round the opposite side of the chest. The arm is kept in a sling bent to a right angle. Should the displacement persist, the bones may be wired

together after bringing the cartilaginous surfaces into contact, the wires being placed so as not to encroach on the joint surfaces. Either they may be passed through the bones vertically, or as a mattress suture from before backwards.

Dislocation of the Shoulder occurs almost as frequently as all the other dislocations of the body put together. The shallowness of the glenoid cavity, the size of the head of the humerus, the laxity of the capsule, the extent and force of the movements possible, and the exposed position of the shoulder, explain the great frequency of the accident. It usually results from falls upon the hand or elbow, the arm at the time of the accident being widely outstretched. The weak lower and inner part of the capsule first yields, the head of the bone being primarily displaced downwards into the axilla (subglenoid variety), and then, according to the direction of the force, or the character of the subsequent manipulations, the head travels either

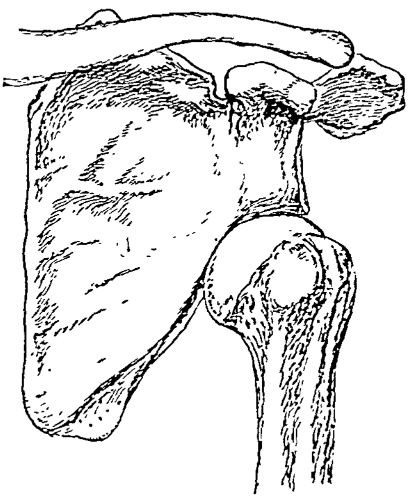


FIG. 400—SUBGLENOID DISLOCATION OF SHOULDER.

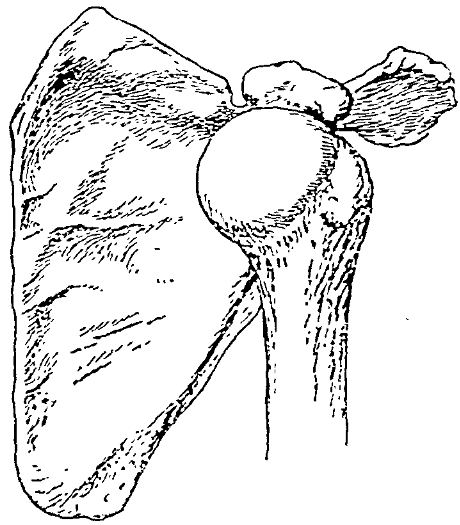


FIG. 401.—SUBCORACOID DISLOCATION OF SHOULDER.

forwards (subcoracoid or subclavicular dislocation) or backwards (subspinous). Falls on the elbow or shoulder may, however, cause a direct forward or backward displacement.

The **Signs** of a dislocation of the shoulder are sufficiently obvious, and certain characteristic features are present in almost all varieties. (1) The shoulder looks flattened, owing to displacement of the head inwards (Fig. 402), and as a result of this the acromion process is unduly prominent, and a hollow is felt below it, occupied by the tense deltoid. (2) The head of the bone lies in some abnormal position, and the glenoid cavity is empty. (3) The elbow is displaced away from the side, and it is impossible to make it touch the chest wall at the same time that the hand is placed on the opposite shoulder (Dugas' test); this does not always obtain in the subcoracoid type. (4) The vertical measurement round the axilla is increased in all the varieties (Callaway's test); whilst inspection reveals a lowering of

the anterior or posterior axillary fold (Bryant's test). (5) A ruler or straight-edge can be made to touch both the acromion process and the outer condyle of the elbow in most cases of dislocation (Hamilton's ruler test); this is impossible when the head of the bone is in its normal position, but can also occur in fractures of the anatomical neck. At the same time, the usual signs of a dislocation, *viz.* rigidity and local bruising, are also present. Stereoscopic radiography is, of course, invaluable for diagnostic purposes.

Subglenoid Dislocation (Fig. 400) is always the primary condition when due to a fall upon the outstretched arm, but is not often seen, since further displacement usually occurs before the case comes under observation. The head of the bone passes down into the axilla, resting against the outer border of the scapula below the glenoid cavity, between the subscapularis above and the teres minor below,

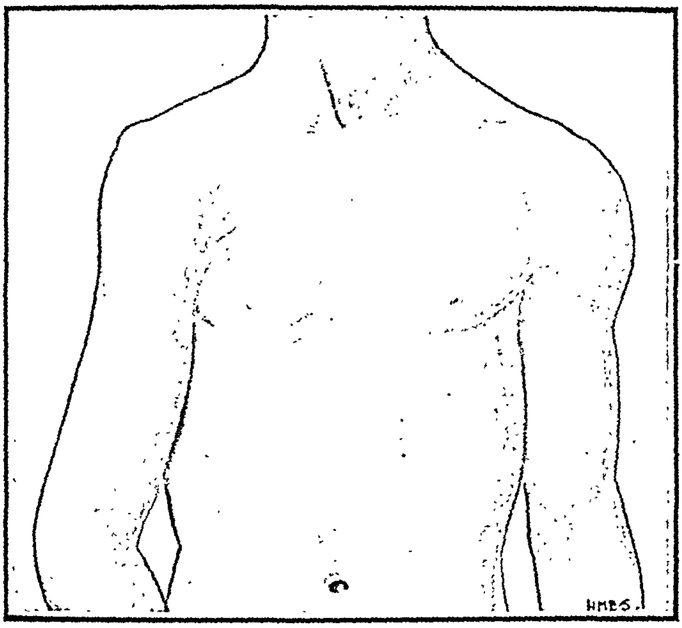


FIG. 402.—SUBCORACOID DISLOCATION OF THE RIGHT SHOULDER.

with the long head of the triceps behind. The capsular ligament and muscles passing to the tuberosities are torn, whilst the axillary vessels and nerves may be seriously compressed, leading to numbness of the fingers. The head of the bone is felt in the axilla, and the anterior axillary fold is much lowered; the elbow is directed away from the side and slightly backwards; the arm is lengthened, perhaps to the extent of 1 inch, whilst the forearm is usually flexed. The lower edge of the glenoid cavity is sometimes broken off, and then reduction with crepitus is easily accomplished, but the displacement as readily recurs.

In a few cases the arm has been abducted and displaced vertically upwards, although the head of the bone was in the usual position of a subglenoid dislocation, constituting the *luxatio erecta*.

Subcoracoid Dislocation (Figs. 401 and 402) is the most common variety. The head of the bone lies under the coracoid process on

the anterior part of the neck of the scapula, immediately in front of the glenoid cavity, the anatomical neck impinging on its anterior border. In this position it lies over the tendon of the subscapularis, which is either torn or stretched across the neck as a tense band, considerably impeding reduction. The muscles attached to the great tuberosity may be stretched, resulting in marked external rotation of the limb (subcoracoid variety), or they are torn, or even the great tuberosity itself pulled off, the humerus being then rotated inwards (intracoracoid variety). The elbow is displaced backwards and outwards, and the head of the bone can be felt on rotation of the arm under the outer third of the clavicle. Little alteration is produced in the length of the arm.

The **Subclavicular** variety is uncommon, and merely an exaggeration of the subcoracoid. The head of the humerus passes further inwards, and lies deeply under the pectoralis minor, on the second and third ribs. The elbow is markedly separated from the side and directed a little backwards, whilst distinct shortening is present.

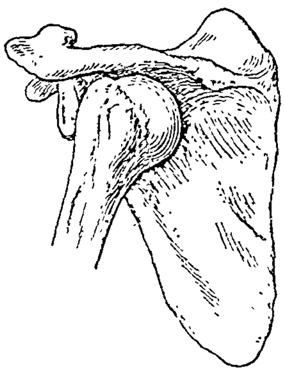


Fig. 403.—Subspinous Dislocation of Shoulder.

The **Subspinous Dislocation** (Fig. 403) is unusual. The head lies in the infraspinous fossa, immediately behind the glenoid cavity, between the infraspinatus and teres minor muscles, the subscapularis being generally torn. The elbow is displaced considerably forwards, but can be made to touch the chest wall; the arm is rotated inwards, so that the hand is thrown across the front of the body. There is usually a marked hollow in front of the shoulder, whilst a prominence is caused behind by the head of the bone in its false position. The length of the arm is often unaffected, but if any change is present, it is slightly lengthened.

A few cases have been described of what is known as a **Supracoracoid Dislocation.** The head of the bone is displaced upwards, and either the coracoid or acromion process is broken, more commonly the former. Replacement with crepitus is easily obtained, but the dislocation is liable to recur.

The **Treatment of Dislocation of the Shoulder** consists in reduction by manipulation or extension.

1. For *reduction by manipulation* an anæsthetic is always advisable, but must be given with caution. Many methods have been suggested, of which the following are the more important. Not unfrequently, however, when the muscles are relaxed, any slight rotary movement suffices to 'put the bone in.'

Kocher's Method for Subcoracoid Dislocations.—The surgeon, standing in front of his patient, who is seated or reclining, and supported by an assistant, grasps the flexed elbow with one hand, and by leaning on this produces slight extension. With the other hand he grasps the wrist and rotates the arm firmly and steadily outwards as far as

it will go, the elbow being pressed to the side (Fig. 404). Distinct resistance will be felt, due to the contraction of the subscapularis, which must be tried out by maintained pressure in the position described. At length the tension of the muscle gives, and this allows the head of the humerus to slip slightly downwards towards the axilla and finally to roll out beneath the acromion, and may suffice to effect reduction. If the limb is still displaced, the elbow should be drawn steadily forwards and upwards as far as it will go, with the humerus still fully everted (Fig. 405), whilst finally the arm is rotated inwards so as to carry the hand towards the opposite shoulder, and the elbow drawn across the chest and lowered (Fig. 406). All these movements should be carried out steadily and evenly, and without undue force or jerking for fear of fracturing the surgical neck of the bone.

2. *Extension* may be employed in different ways, the object being to overcome the tension of surrounding ligaments and muscles. It may be applied directly downwards by the surgeon grasping and

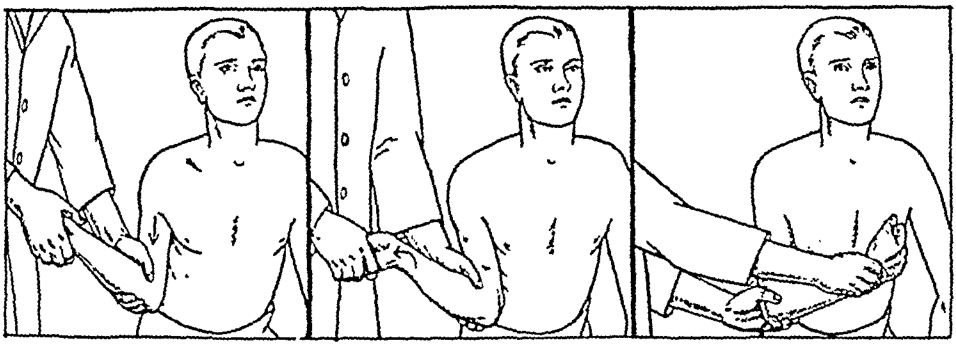


FIG. 404. FIG. 405. FIG. 406.

FIGS. 404-406.—KOCHER'S METHOD OF REDUCTION OF A SUBCORACOID DISLOCATION OF THE SHOULDER.

pulling on the arm, whilst his unbooted foot is used as a counter-extending force in the axilla, the patient lying flat on a mattress placed on the ground, and the surgeon sitting by the side. Another plan consists in using the knee as a fulcrum instead of the heel, the patient sitting in a chair; one assistant makes traction on the limb abducted to a right angle, whilst another makes counter-extension and steadies the scapula.

After-treatment.—The whole arm is bandaged to the side for a week or ten days, so as to allow the extravasated blood to be absorbed and the rent in the capsule to be closed. The arm is then carried in a sling, and gentle movements (other than abduction) permitted; flexion, extension, and rotary movements must be gradually restored, and finally abduction. In three to four weeks a full range of movements should be possible in the absence of complications.

Associated fracture of the lower margin of the glenoid cavity requires more careful and prolonged fixation, so as to prevent recurrence of the trouble. When the dislocation is complicated by fracture of the great tuberosity, the head of the bone must be reduced, and the

limb fixed in abduction so as to approximate the fractured surfaces. Radiography will be essential in order to test the position of the head of the bone and of the fragment; if this is unsatisfactory, open operation to fix the tuberosity by screw or bone peg must be undertaken.

Recurring or Habitual Dislocation of the shoulder is an uncomfortable condition in which the head of the bone slips out of place without sufficient cause. It is due either to irregular shape of the head, or more often to a relaxed capsule, possibly due to too early and vigorous mobilization after a traumatic dislocation. Prevention is possible if the patient can remember never to undertake certain movements, *e.g.* hyper-abduction of the arm, as in doing the hair; but more often relief by operative measures will be acceptable. (1) It is possible to expose the capsule from the front and take in the slack, either by excising an elliptic portion, or by folding it into suitable creases, which are fixed by sutures; in many cases this will suffice. (2) A more certain result may be anticipated to follow *Clairmont's operation.* Two incisions are required back and front of the joint, exposing the anterior and posterior borders of the deltoid. Through the anterior incision the muscle is split longitudinally, and opened up so as to enable the surgeon to define and enlarge the quadrilateral space. Through the posterior incision a slip-like flap of the deltoid is detached from below, but left attached above, and its nerve-supply carefully guarded. Its free end is passed through the quadrilateral space, and sutured to the split anterior portion of the deltoid. This operation is most reliable, as the transposed flap acts not only as a sling to keep the head of the bone in place, but also tightens up when abduction is attempted.

FIG. 407.—BACKWARD DISLOCATION OF THE ELBOW.

Dislocations of the Elbow-Joint are not very uncommon, occurring particularly in young people, and are due to either direct or indirect violence. The diagnosis is often difficult from the amount of swelling that quickly follows. A careful investigation of the relative position of the bony points, and of the degree of mobility of the different parts on each other, is essential in order to arrive at a definite conclusion as to the exact nature of the lesion. In cases of doubt a radiograph should be taken.

1. **Dislocation of Both Bones** may occur either *backwards, forwards,* or *laterally.*

The **backward** variety (Fig. 407) is that most often seen. If the coronoid process remains unbroken, it sometimes becomes locked in the olecranon fossa, and renders the arm immobile; if, however, it is detached, considerable mobility of both bones occurs, with crepitus. The forearm is semi-flexed, the hand held midway between pronation and supination, and the displaced bones form a considerable swelling at the back of the joint, above which is a marked hollow, crossed by the triceps. The lower end of the humerus projects in front, and the artery and the soft parts are displaced forwards. The measurement from the acromion process to the external condyle remains unaltered, but that from the condyle to the styloid process of the radius is distinctly shortened, and the distance between the condyles and the olecranon process is increased.

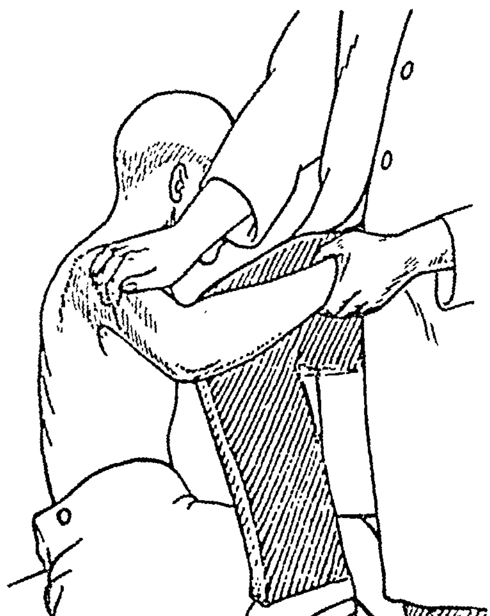


FIG. 408.—REDUCTION OF BACKWARD DISLOCATION AT THE ELBOW.

Dislocation **forwards** of both bones rarely occurs without fracture of the olecranon, although a few cases are on record. The displacement is readily detected, the forearm being lengthened perhaps to the extent of an inch. The arm is in a condition of flexion, and, indeed, the accident can only take place from falling backwards on the point of the elbow when in this position. The triceps muscle will be considerably torn.

Lateral dislocations of the forearm are almost always incomplete, and are rare apart from fractures; the bones may be displaced either inwards or outwards, the latter being the more common. They are recognized by a careful examination of the relative position of the bony prominences and by stereoscopic radiography.

2. **Dislocation of the Ulna alone** occurs only in a *backward* direction. It is very uncommon owing to the position and strength of the orbicular and oblique ligaments and of the interosseous membrane. In a position of full pronation, however, forcible adduction of the forearm may determine this displacement without extensive ligamentous lacerations, which, indeed, have not been noted in any of the cases observed.

In the **Treatment** of the above dislocations all that is necessary is to unhitch the interlocking bony prominences, so as to allow the bones to return to their normal positions by muscular contraction. This is usually accomplished by the method described by Sir Astley

Cooper. The patient being in a sitting position, the surgeon presses backwards, with his knee in the bend of the elbow, against the lower end of the humerus; at the same time he grasps the patient's wrist, and slowly and forcibly bends the forearm (Fig. 408). The arm is bent to a right angle and kept at rest for two or three weeks at least, so as to permit repair to be accomplished perfectly, and to minimize the likelihood of a development of traumatic myositis ossificans in the substance of the brachialis anticus (p. 466), a by no means unfrequent sequela.

3. **Dislocation of the Radius alone** may occur either *forwards, backwards*, or *outwards*.

The **forward** dislocation (Fig. 409) is that usually seen, and results from falls on the hand when the forearm is in a state of extreme pronation, or from forcible traction upon the hand, or from direct injury applied to the back and outer side of the elbow. The head of the radius rests against the lower end of the humerus in the hollow above the capitellum, and the most characteristic feature consists in the inability of the patient to flex his forearm, owing to the bone impinging against the lower end of the humerus. It can be readily detected in this situation, rotating with the movements of the forearm, whilst a deep hollow is felt behind, immediately below the external condyle. The forearm is somewhat flexed, and midway between pronation and supination; the former act can be satisfactorily accomplished, but supination cannot be carried further than halfway. A marked fulness exists on the anterior aspect of the limb when the arm is extended. Fracture of the upper third of the ulna sometimes accompanies this accident, especially when produced by direct violence. If this luxation is not reduced, great impairment of the mobility of the limb results, flexion beyond an obtuse angle becoming impossible. **Treatment.**—Reduction is accomplished by traction from the wrist, with the forearm flexed to a right angle, combined with pressure over the head of the bone. Owing to the fact that the orbicular ligament is ruptured, the deformity is likely to recur, unless the limb is kept completely flexed in order to relax the biceps; full supination must also be maintained. Active movements of the limb must be interdicted for three or four weeks. In old-standing cases excision of the head of the bone is desirable.

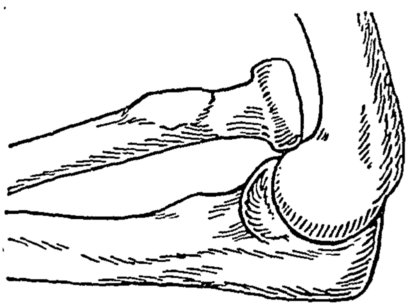


FIG. 409.—DISLOCATION OF THE RADIUS FORWARDS.

Dislocation **backwards** is less common. The head lies behind the external condyle on the outer side of the olecranon, where it can be detected on rotating the limb. The forearm is flexed, and the limb pronated. Even if left unreduced, it leads to but little inconvenience.

Dislocation outwards is also rare, the head of the bone being displaced to the outer side of the external condyle, where it can be felt,

causing considerable impairment of movement. Reduction is accomplished without difficulty, or, if necessary, the head may be excised.

Occasionally a rare form of dislocation is met with in which the ulna passes backwards and the radius forwards, resulting in great deformity.

A very common accident in children under four years of age consists in a **subluxation of the head of the radius downwards** within the orbicular ligament, so that a fold of synovial membrane slips up and becomes nipped between the head and capitellum. It results from forcible traction of the hand, as from pulling up a child roughly after it has fallen, and is a common nursery accident popularly known as **pulled elbow.** The limb becomes fixed in a position of slight flexion and with the hand pronated, and the child cries out with the pain; it is readily treated by completely flexing the limb, and subsequently extending and fully supinating it, and leaves no bad results.

It must not be forgotten that here merely the pure dislocations have been described. In actual practice **complications** of a serious nature are frequently present in the shape of fracture of one or both condyles, which add to the difficulty of diagnosis, apart from radiography, and even then the results of treatment may be unsatisfactory. Abundant callus is formed, and considerable impairment of function is liable to ensue.

Dislocation of the Wrist is a very uncommon accident, and may occur *forwards* or *backwards.* The lower ends of the radius and ulna project under the skin, and the styloid processes retain their relative positions; it is thereby easily distinguished from a Colles's fracture. Reduction is readily effected, and the hand should be kept at rest for some four to six weeks in a slightly dorsiflexed position.

Occasionally the radius, carrying with it the hand, is dislocated from the lower end of the ulna, as a result of forcible pronation, which results in laceration of the inferior radio-ulnar ligaments, and probably of the lowest portion of the interosseous membrane. The triangular fibro-cartilage is in some of these cases loosened, and its mobility may subsequently give rise to a painful weakness of the wrist. The ulna projects backwards, and its reduction is easy; but some laxity of the inferior radio-ulnar joint may persist, unless the bones are kept firmly together by suitable bandaging.

Dislocations of Various Carpal Bones have been described, and radiography has demonstrated that they are by no means uncommon. The semilunar is probably more frequently displaced than the other carpal bones. In reality this displacement is a posterior dislocation of the distal part of the carpus. Usually the posterior ligaments of the semilunar are broken and it becomes rotated forwards through anything up to 180 degrees, so that its os magnum articular surface may come to look directly upwards (Fig. 410). It is associated with much pain in the wrist and limitation of movement, and oftentimes there is an accompanying fracture of the scaphoid. Reduction can usually be effected by strong and steady traction on the fingers and thumb, exerted by an assistant, counter-traction being maintained by passing the upper arm through a loop of webbing attached to some fixed point. Many cases will slip into position during traction,

he tension on the flexor tendons moulding the bone into its right position; but in others some manipulation will be required. In old-standing cases operation may be necessary and the bone excised. A plaster cast is applied for three weeks following the reduction.

Dislocations of the Metacarpal Bones and Phalanges are not unfrequent, but need no special mention, except in the case of **Dislocation Backwards of the First Phalanx of the Thumb.** The chief interest here lies in the difficulty experienced in reduction, which was formerly attributed to the head slipping between the two portions of the flexor brevis pollicis and being grasped by them, as a button in a button-hole. It has now been shown that there are two much more important factors, *viz.* the tension of the long flexor tendon, which hitches round the neck (Fig. 411), and the arrangement of the glenoid ligament. This fibro-cartilaginous structure passes between the two heads of insertion of the short flexor muscles, and is thus incorporated between the two sesamoid bones; whilst firmly attached to the base of the phalanx, it is but loosely connected with the head of the metacarpal bone, so that it accompanies the phalanx in its dislocation, and will then be situated immediately behind the head of the metacarpal, so as to prevent reduction. **Treatment.**—Traction and manipulation are always attempted in the first instance. The thumb is grasped by a suitable apparatus and hyper-extended to a right angle, thus making the head of the metacarpal project still further through the muscular interspace, and, as it were, enlarging the button-hole. Still maintaining the traction, the thumb is rapidly flexed into the palm, the metacarpal bone being at the same time pressed inwards. Should this fail, as it often will, a sterilized tenotome should be inserted in the middle line of the thumb behind, immediately above the base of the phalanx, and should be pushed on till it reaches and divides the glenoid fibro-cartilage between the sesamoid bones; this little manœuvre will at once render replacement simple.

FIG. 410.—DISLOCATION FORWARDS OF CARPAL SEMILUNAR.

Dislocation of the Hip is fortunately not very common, as it is a condition of extreme gravity. The depth of the socket in which the femur rests, and the strength of the muscles and ligaments surrounding the articulation, explain the comparative unfrequency of the accident. It always results from violence applied to the feet or knees, or, if the legs be fixed, to the back. It is rarely met with except

in young people or adults, since after the age of forty-five fractures of the neck of the bone are much more likely to occur.

Four chief varieties of dislocation are described, in two of which the head of the bone is displaced posteriorly, and in two anteriorly. The former are known as the *Dorsal* and the *Sciatic* varieties, in which the head of the bone occupies some situation on the dorsum ilii, determined by the integrity or not of the obturator internus tendon. The anterior dislocations are known as the *Obturator* (or *Thyroid*) and the *Pubic*; in the former the head of the bone is located in the obturator notch, and in the latter upon the pubic ramus. The relative frequency of these dislocations is as follows: About 50 to 55 per cent. of the cases are dorsal, 20 to 25 per cent. sciatic, 10 to 15 per cent. obturator, and 5 to 10 per cent. pubic. In addition to the above, many other slight modifications have been described, which it is unnecessary further to particularize.

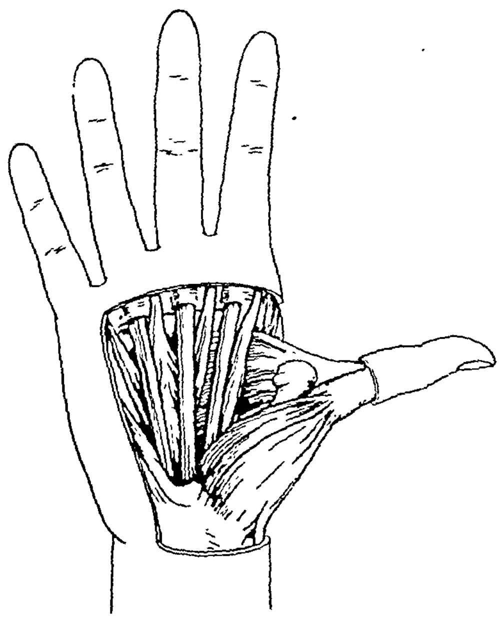


FIG. 411.—DISLOCATION OF THUMB, SHOWING HEAD OF METACARPAL BONE PROTRUDING FORWARDS BETWEEN THE HEADS OF THE SHORT FLEXOR MUSCLE.

Mechanism.—In considering these dislocations, the relative strength or weakness of the different parts of the capsule and its surrounding structures must be remembered. The weakest part of the capsule is placed below and behind, and it is through a rent in this position that the head of the bone most frequently escapes. In front, the ilio-femoral or Y-shaped ligament of Bigelow is a structure of much strength, on the integrity of which depends the fact whether the displaced head of the bone shall occupy some definite position or be freely movable. Bigelow, to whom we owe so much in the elucidation of the mechanism of these dislocations, has divided them into two classes—the *regular* and the *irregular*—according to whether this ligament is intact or completely lacerated. Posteriorly, the plicated tendon of the obturator internus is the most important structure, and the position and level of the bone on the dorsum ilii depend in some measure on whether it remains intact or is ruptured. It must also be remembered that the ligamentum teres is relaxed when the thigh is forcibly abducted, and is made tense by adduction.

The limb is usually in a position of *abduction* at the moment of dislocation, the head of the bone escaping through a rent in the lower and back part of the capsule. The type of accident responsible for this is a fall with the legs widely separated or when the limbs are drawn forcibly apart, as, for instance, when one leg is placed on a boat just

moving away from a pier on which the other is fixed. The direction of the violence, or the subsequent manipulations performed by willing but ignorant friends, or the voluntary movements of the individual, determine what form of dislocation will be subsequently produced. If the limb is externally rotated and extended, or the trunk is hyper-extended and the limb remains fixed, the head travels forwards, and either the pubic or obturator variety results. If, however, the leg is inverted and flexed the head of the bone passes backwards, and either the dorsal or sciatic form is produced. Again, in the posterior dislocations, if the obturator internus tendon remains intact, it may hitch across the front of the neck, and prevent any further upward displacement of the bone, thus giving rise to the so-called sciatic variety, or as Sir Astley Cooper called it, the 'dorsal below the tendon'; but if the tendon is ruptured, or if the head of the bone slips in front of it, there is no obstacle to its upward displacement on the dorsum ilii.

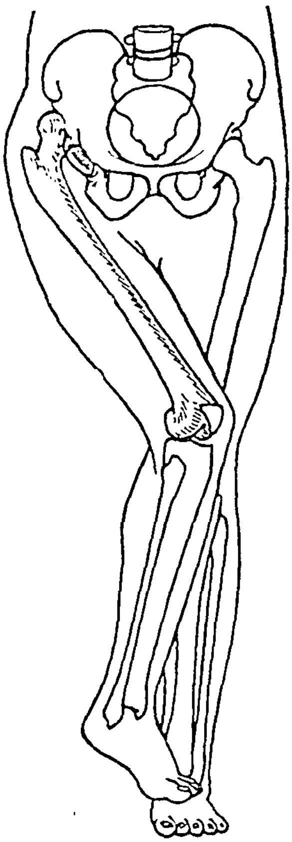


FIG 412.—DORSAL DISLOCATION OF THE HIP.

Dislocation may also result when the limb is in a position of *adduction*, a direct dorsal dislocation being thus produced, the head of the bone escaping from the capsule above the tendon of the obturator internus; such an accident is sometimes associated with fracture of the posterior lip of the acetabulum. The type of violence leading to this occurrence is when a heavy weight falls on the back of a person whilst kneeling, or when, the knee being flexed, the body is thrust forwards, so that the limb is forcibly inverted. If, however, the thigh is in a position of extreme flexion, the head may be displaced below the tendon of the obturator internus, and the sciatic variety will then result.

1. **Dorsal Dislocation** (Fig. 412).—The head of the bone lies on the dorsum ilii, a variable distance above and behind the acetabulum, and always above the obturator internus tendon. It may be detected on manipulation of the limb, although in muscular subjects this is difficult. The ligamentum teres is necessarily ruptured, as also the capsule, the rent being situated either below or above the obturator tendon, according to whether the dislocation is due to forcible abduction or adduction. The small external rotator muscles are often lacerated, and perhaps even the glutei and the pectineus. The ilio-femoral ligament usually remains intact. The great sciatic nerve is sometimes compressed or contused. The trochanter is raised above Nélaton's line (p. 604) and approximated to the anterior superior spine; the ilio-tibial band of fascia is therefore relaxed, and there is

considerable shortening of the limb, amounting sometimes to 2 or 3 inches. The leg is in a position of flexion, adduction, and inversion, so that the axis of the femur crosses the lower third of the sound thigh. The knee is semiflexed, and the ball of the great toe rests against the opposite instep; the heel is somewhat raised. A marked hollow is felt in the upper part of Scarpa's triangle, the main vessels appearing to be unsupported.

The **Diagnosis** should be easy, the only difficulty being experienced in distinguishing it from an impacted intertrochanteric fracture. The character of the accident, the presence of adduction and inversion, the increased breadth of the trochanter in the case of fracture, and the abnormally placed head of the bone in dislocation, are the points to which attention must be directed.

2. **Sciatic Dislocation,** or 'dorsal below the tendon,' is one in which the head of the bone is prevented from travelling upwards to the dorsum ilii by the integrity of the obturator internus tendon. It may occur either from forced abduction of the limb, or from extreme flexion in the adducted position. The lesions of muscles and ligaments are practically the same as for the dorsal variety. The ilio-femoral ligament is uninjured.

The **Signs** resemble those of a dorsal dislocation, but are less marked. There is less shortening, often not more than ½ to 1 inch; the limb is flexed, adducted, and inverted, but the axis of the femur is directed across the opposite knee, and the great toe rests against the ball of the great toe of the opposite side. The head of the bone is often much less distinct, owing to the greater thickness of the glutei muscles at the lower level.

Treatment of the Two Backward Dislocations is effected in much the same way, whether the dorsal or sciatic variety is present. The most usual method is that of *circumduction*, so accurately worked out by Bigelow. The patient is anæsthetized, preferably on a mattress placed on the floor. The leg is first flexed on the thigh, and the thigh on the abdomen, the position of adduction and internal rotation being still maintained, so that the knee extends beyond the middle line of the body. This position is maintained for some moments, and then the limb is lifted up and freely circumducted outwards, and brought rapidly down into a position of extension parallel with the other. By this manœuvre the tense structures in front of the joint are relaxed, and then the head of the bone is made to retrace its course towards the rent in the capsule, and finally directed upwards into the acetabular cavity. These movements can be tersely summarized: '*Lift up, bend out, roll out.*'

If this plan does not succeed, the following method of *traction* may be employed: The patient, lying on his back, is firmly fixed by a bandage or towel passed over the pelvis and secured to two or three hooks or staples driven into the floor. The surgeon stands over the patient, whose thigh is flexed to a right angle on the abdomen, as also the knee upon the thigh. The surgeon's arms are passed under the knee sufficiently far to enable him to grasp his own elbows, and the front of the leg is steadied against the operator's perineum, Direct

and forcible traction upwards as if to lift the patient from the floor can now be made, and this is often sufficient in itself to lift the head of the bone into the acetabulum. If this is unsuccessful, the same process is repeated in a position of internal or external rotation. The above plans, combined with the use of an anæsthetic, rarely fail in reducing a backward dislocation of the hip, and hence *extension by means of pulleys* is rarely required.

3. **Obturator (or Thyroid) Dislocation** (Fig. 413).—The head of the bone in this case passes downwards through a rent in the lower part of the capsule, and its position is subsequently but little altered, a slight forward and upward movement being alone superadded. The ilio-femoral ligament is untorn, but the pectineus and adductors are very tense, or may even be lacerated; the ligamentum teres is, of course, ruptured. The head lies on the obturator externus muscle, and can be detected in the perineum. The trochanter is less prominent than usual, and, indeed, its normal position may be represented by a depression. The limb is slightly abducted and everted, as well as lengthened, perhaps to the extent of 2 inches, though this is more apparent than real. It is also flexed, owing to the tension of the ilio-psoas muscle, and advanced before the other, with the toes pointing outwards. The adductor longus tendon stands out prominently, and much pain may be experienced from pressure on the obturator nerve. If the patient stands the body is bent forwards, and if the dislocation remains unreduced the patient may be able to walk without much pain or inconvenience, though in a more or less stooping attitude.

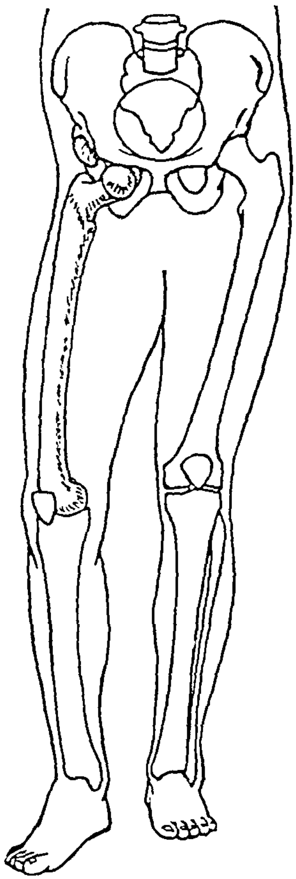


FIG. 413.—DISLOCATION OF THE HIP FORWARDS: OBTURATOR VARIETY.

4. **Pubic Dislocation** (Fig. 414).—In this variety the head of the bone either escapes from the joint below, or may be forced out in front and to the inner side of the ilio-femoral ligament as a result of hyper-extension of the trunk. The head lies on the horizontal ramus of the pubes, just internal to the anterior inferior spinous process of the ilium, where it can be felt rolling under the finger on any movement of the limb. The vessels are pushed inwards, and considerable pain may be felt down the limb from pressure on the anterior crural nerve. The ilio-femoral ligament is untorn, whilst the ligamentum teres and capsular ligament are ruptured; the small external rotator muscles, with the exception of the obturator internus, are usually torn. There is marked flattening of the hip, the trochanter being

approximated to the middle line and raised. The limb is shortened to the extent of 1 inch, and there is considerable abduction and eversion, so that the inner aspect of the limb looks forward. The thigh is slightly flexed to relax the ilio-psoas muscle.

Treatment of the obturator and pubic dislocations is undertaken along similar lines as for the posterior dislocations. The patient is anæsthetized; the knee is flexed, as also the thigh upon the abdomen, but in a position of abduction; pressure backwards upon the head of the bone by the hands of an assistant will assist it in retracing its course towards the rent in the capsule. Circumduction inwards follows, and on extension of the limb the head again enters the acetabulum. The obturator variety may sometimes be reduced by upward and outward traction when the limb has been flexed to a right angle in the abducted position, the unbooted foot being placed against the pelvis to steady it.

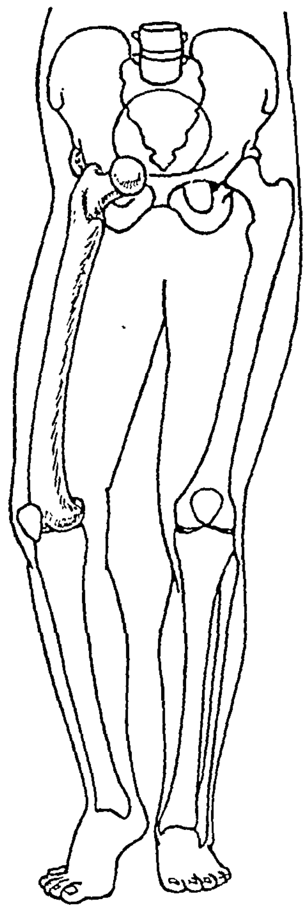


Fig. 414.—Dislocation of the Hip forwards: Pubic Variety.

After reduction of any form of dislocation of the hip, the patient should be kept in bed with the legs tied together for about a week or ten days, and then movements, either passive or active, may be permitted, but only with great caution, and with the patient still in bed. Unless protected by a plaster-of-Paris spica, he ought not to attempt to stand or walk for three weeks.

Should the dislocation recur, it may be due to fracture of the posterior lip of the acetabulum, or to some involuntary movements of the patient, or perhaps to the fact that the displacement has not been fully reduced. Under such circumstances further attempts at replacement should be undertaken, and the limb subsequently kept immobilized, and extended in an abduction frame for some weeks.

Dislocation of the Patella may occur *outwards, inwards,* or *edgeways*. A dislocation upwards resulting from rupture of the ligamentum patellæ is sometimes described, but it is scarcely to be included in the same category as the others. The displacement may be complete or incomplete; in the former, the capsule is always lacerated; in the latter, not necessarily so.

The **outward** is the only variety commonly seen, and then, on account of the obliquity of the limb, it may result from muscular action, especially in people suffering from genu valgum; it also arises from direct violence. In either case it occurs most frequently when the limb is extended, since during flexion the bone is firmly lodged in the intercondyloid notch. It lies upon the outer surface of the

condyle, with its inner margin projecting forwards, and is easily felt, whilst the knee appears flattened and broader than usual, the intercondyloid notch being plainly distinguishable in the position usually occupied by the patella. *Reduction* may take place spontaneously, but is usually effected by manipulation. The thigh is flexed on the abdomen, and the knee extended, so as to relax the quadriceps, and then a little pressure on its outer margin causes the bone to slip back into place. Subsequent treatment consists in keeping the limb in a position of extension for some four weeks in a plaster cast.

The **inward** dislocation is rare, being always due to direct violence. In characters and treatment it is the exact converse of those met with when the bone is displaced outwards.

A dislocation edgeways, or **Vertical Rotation** of the patella, is an interesting condition in which the bone is said to be twisted vertically upon its own axis, and even to have been turned completely round.

Recurrent dislocation of the patella is always associated with genu valgum, or with laxity of the extensor muscles from paralysis. In the former case it may be cured by correcting the deformity by means of osteotomy of the femur; but sometimes the synovial membrane of the knee-joint on the inner side will also require to be braced up by excision of a portion and suture of the margins of the defect. In this, as also in the paralytic variety, when the extensor muscle is slack, the tubercle of the tibia should be chiselled off, together with the ligamentum patellæ, and re-attached lower down.

Dislocations of the Knee may occur *laterally*, as also *forwards* or *backwards*. When due to disease of the joint, the backward dislocation is commonest; but when arising from traumatic causes, the lateral is the most frequent.

The **lateral** displacements are rarely complete, and are usually associated with a certain amount of rotation; the leg is partially flexed. Reduction is effected without difficulty.

Dislocation of the tibia **forwards** is more common than displacement backwards. It is generally complete, the lower end of the femur projecting into the popliteal space, and compressing the vessels, so that gangrene not unfrequently follows. The upper end of the tibia, carrying with it the patella, lies in front, forming a well-marked swelling with a hollow above it. There is usually considerable shortening of the limb if the articular surfaces overlap.

Dislocation of the tibia **backwards** is a much rarer accident, and is also as a rule complete. The signs are exceedingly characteristic, the pressure effects upon the popliteal vessels and nerves often resulting in gangrene.

Reduction of either of these conditions is easily accomplished by traction on the limb, whilst the thigh is flexed, combined with manipulation in order to guide the head of the tibia into its normal position. The limb must subsequently be kept at rest in a plaster cast for a period of anything up to three months, according to the degree of initial injury. If the joint is mobilized too early, the damaged muscles and ligaments will not return to normal and a flail joint will result.

Internal Derangement of the Knee-Joint is so important a subject

and leads to so many mistakes both in diagnosis and treatment that it must be discussed somewhat fully. The shape of the articular surfaces of the femur and tibia is certainly not such as to guarantee a stable joint, considering the severity of the strains to which it is exposed, and the freedom of movement present. The most powerful ligaments are of course attached posteriorly so as to limit extension, and the crucial ligaments are needed to assist in this check, and to prevent rotation. To serve as elastic buffers, the interarticular cartilages are interposed, fixed to the head of the tibia, and to occupy the spare space a fatty pad of considerable size is present. It is obvious that many injuries can occur in these structures, and considerable discrimination is required if accurate diagnosis and treatment are to be effected.

1. *Ligamentous Sprains and Strains* are common, and most frequently involve the internal lateral ligament; the reason for this is obviously the mechanical disadvantage to which this ligament is exposed by the displacement outwards of the upper end of the femur to engage the acetabulum. This lesion has already been noticed (p. 690), but one would draw attention to the frequent recurrence of slight injuries to this structure with repeated attacks of mild synovitis. Tenderness is usually experienced over the extreme inner border of the tibia (Fig. 415), and much can be done to protect the damaged ligament by deflection of the weight to the outer side of the limb; this is effected by thickening the inner side of the heel and sole of the boot.

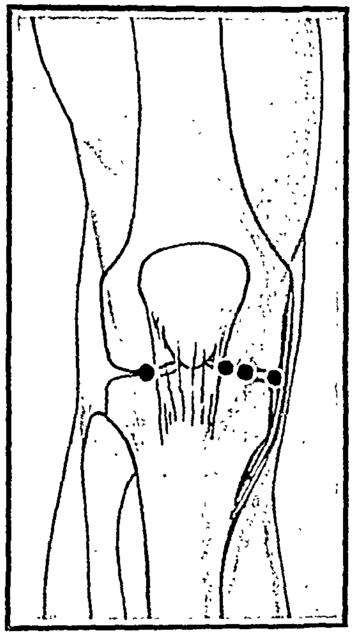


FIG. 415.—POINTS OF MAXIMUM TENDERNESS IN VARIOUS CONDITIONS OF KNEE-JOINT.

2. *Thickening of the Fatty Pads* behind the patella is another common source of functional disability and pain. Hæmorrhagic infiltration into this structure causes it to project backwards into the joint cavity, and exposes the free edges to the likelihood of being nipped between the bones in full extension of the joint. This in turn produces increased thickening of the pad, and the fimbriated edges become fibrous and hard, projecting into the joint cavity like the villi often seen in osteo-arthritis, and perhaps becoming adherent to the back of the joint.

The patient complains of discomfort and pain in the knee, with recurring attacks of slight synovial effusion. The chief pain is experienced in complete extension, and this is referred to either side of the patellar ligament (Fig. 415), where the thickened pads of fat can be felt. From time to time acute pain is experienced during walking owing to the nipping of the synovial tags, or the drag of adhesions, but there is no locking of the joint, and the synovial reaction is slight.

With careful manipulation the fatty tabs and fringe can sometimes be felt rolling in the joint on movement.

Treatment.—In the early stages when it appears likely that hæmorrhage has recently occurred, all that is required is rest and support by a firm flannel bandage, followed by a gradual restoration of the functions of the joint. In old-standing cases where painful limitation of movement suggests the existence of adhesions, manipulative treatment under an anæsthetic through a full range of flexion and extension may suffice to snap the adhesions and restore the joint to usefulness.

If this fail and the condition is of a chronic character, the mobility of the joint must be limited by the use of a knee cage or splint, which prevents full extension. Counter-irritation may be of some use, and massage to tone up the quadriceps, which in chronic cases is almost always atrophied; it also helps to tighten up the attachment of the subcrureus to the synovial membrane, and thus pull the fatty pad aside. Operation to remove these structures is rarely necessary, and not very satisfactory.

3. *Rupture of the Crucial Ligaments* results from twisting injuries, which are more severe than those which occasion simple sprains, and may be accompanied or not by fracture of the tibial spine. The pain and hæmorrhagic effusion produced are so great that a diagnosis is not often made at once, except when radiography reveals an injury to the spine of the tibia. The limb is placed at rest on a back-splint, and it is only at a later date that the persistent weakness of the joint leads to a closer examination, and reveals the fact that abnormal to-and-fro movements are possible, as also perhaps internal rotation. The anatomical arrangement of the crucial ligaments is such that, when intact, inversion of the extended leg is impossible. If the anterior ligament (which is tense in extension of the leg) is torn, the tibia can be displaced forwards with the knee extended; if the posterior ligament (which becomes tense in flexion of the knee) is torn, the tibia can be displaced backwards with the knee flexed—movements which are impossible with unruptured crucials.

Treatment.—If the case is recognized fairly early, the limb is placed on a back-splint and kept at rest with a view to allowing the torn ligament to be repaired by scar tissue; the period of rest is maintained sufficiently long to permit the scar to contract and become firm. To this end a leather knee splint or cage must be used, allowing either no movement or only a very limited range; one similar to that advised for a fractured patella is useful. Operation is probably of little value, since the knee must be fully flexed in order to expose the parts, and careful approximation is in such a position almost an impossibility. The good results claimed for these operations are probably due to the effective after-treatment.

In old-standing cases with much disability Hey Groves has suggested an operation for reconstituting the crucial ligaments, utilizing the semitendinosus tendon for the posterior and a strip of the iliotibial band for the anterior. In either case holes are drilled through the femur and tibia in such a direction that the new ligaments when threaded through them shall lie in the situation of the old; the loose

end is fixed below by stitching. This operation has now been performed in a number of cases, and up to date has given some excellent results.

Where radiography demonstrates that the spine of the tibia is broken, an attempt must be made by manipulation and flexion of the joint to push it up into the intercondyloid notch and so prevent it from hampering movement; after-treatment is as for rupture of the crucials. Failing this manœuvre, the joint must be opened and the portion of bone fixed by a bone-nail or removed.

To open the knee-joint so as to expose the posterior parts, it is best to split or saw the patella vertically and to draw the divided halves and the split ligamentum patellæ and tendon of the quadriceps to either side; when the knee thus opened up is bent, all the posterior structures are easily accessible. The divided bone is subsequently sutured accurately.

4. *Displacement or Rupture of a Semilunar Cartilage* is a very common accident, resulting from sudden violence directed to the knee, usually in the nature of side-slips associated with torsion; slipping from the kerbstone, injuries in mines, or falls in the football field or on the tennis court are the most frequent sources of this lesion. The close attachment of the outer margin of the cartilages to the lateral ligaments or capsule explains the causative influence of lateral strain upon these injuries; whilst in any rotary movement of the knee, only possible with the joint flexed, the pressure of the condyles always modifies the position of the cartilages, which, moreover, are relaxed and more freely movable on the upper surfaces of the tibia in flexion than in extension. The inner cartilage is much more frequently affected than the outer, and the character and extent of the lesion varies much in different cases.

The lateral ligament or capsule usually gives way first, and allows the joint to open up as a result of the leverage applied laterally upon the ankle. The cartilage then slips out from the joint, sometimes tearing the anterior or posterior attachment, more commonly the former (Fig. 416); most frequently, however, the cartilage is broken across (Fig. 417) or split longitudinally (Figs. 418, 419). The former lesion appears constantly after athletic injuries, *e.g.* football, and involves the anterior portion of the cartilage rather than the posterior. In the latter the so-called 'bucket-handle' injury (Fig. 418) is produced in the first place, but either end of the loosened fragment may be subsequently torn, and here again usually in front, and then the handle flaps freely in the joint, and is obviously liable to cause locking. If both ends are torn across, a loose body in the joint results. When the violence ceases, the joint surfaces come together again, and may close on the torn or displaced cartilage, fixing it and locking the joint; or the cartilage may slip back into place and give no indication of its temporary displacement beyond pain.

Repair in cartilage is always imperfect, owing to the fact that vessels penetrate only a very little way into it, and thus the free margin of a torn semilunar cartilage is a very unfavourable tissue for this process. The surfaces, moreover, become covered with endothelium, and this is a still further hindrance.

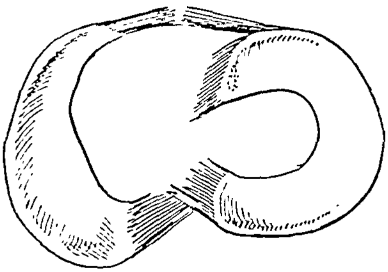


FIG. 416.

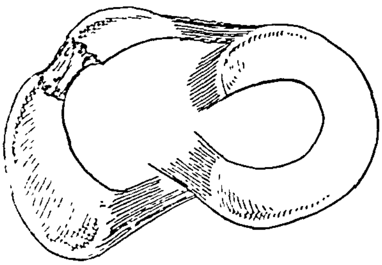


FIG. 417.

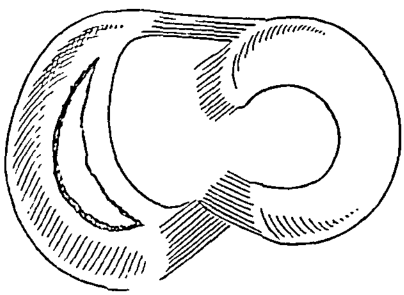


FIG. 418.

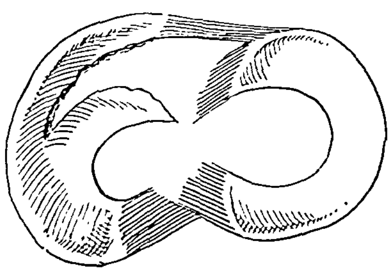


FIG. 419.

FIGS. 416-419.—DIAGRAMS OF VARIOUS TYPES OF INJURY SUSTAINED BY THE INTERNAL SEMILUNAR CARTILAGE.

In Fig. 416 the anterior attachment has been stretched and torn, and the cartilage is consequently loose. In Fig. 417 the cartilage has been torn transversely across, and a weak cicatrix has formed. In Fig. 418 the cartilage has been split longitudinally (bucket-handle injury). In Fig. 419 the anterior end of the bucket-handle has also given way, leaving a loose tag, which often causes trouble.

The **Symptoms** produced by this accident are a sudden sickening pain of much severity, located in the knee, which may become locked in a position of flexion, with inability to extend it. The patient may be able to ' wriggle ' his joint free, or the limb may remain stiff for some hours, or even a day or two, when movement suddenly returns more or less spontaneously, a snap being at the same time felt within the joint. An attack of subacute synovitis usually follows. In other cases the cartilage remains out of place until reduced by the surgeon, with or without an anæsthetic. The usual evidence of this is inability of the patient to extend the knee fully, any attempt to do so causing severe pain in the back of the joint, and possibly the projection of the posterior portion of the cartilage may be detected on careful palpation. Even if full reduction has been effected, the displacement is liable to recur unless sufficient time is permitted to allow firm cicatrization; otherwise the bond of union between the cartilage and the tibia, or between the severed halves of the cartilage, will be loose and elongated, permitting recurrence of the displacement, the cartilage or a portion of it slipping out of place, either externally, where it can be felt, or into the intercondyloid notch, getting nipped and locking the joint temporarily; this is followed by a mild attack of synovitis. As times goes on, this becomes more and more easy, owing to the ligaments of the joint being relaxed from the recurrent attacks of synovitis, and the limb may pass into such a state of chronic weakness as to interfere seriously with the patient's comfort. There is usually a spot of localized pain in the front of the joint, correspond-

ing to the upper surface of the tibia (Fig. 415); possibly there may be some amount of lateral mobility of the leg, and movement of the cartilage may be detected on flexing and extending the knee. The quadriceps muscle is always atrophic, atonic, and relaxed.

The **Diagnosis** is often a matter of considerable difficulty, as many conditions give rise to symptoms akin to those of a displaced cartilage. Recurring *sprains of an internal lateral ligament*, due to want of prolonged fixation, are known by the absence of locking, or of the crepitus usually caused by a slipping cartilage, whilst the tender spot is over the extreme inner edge of the tibia. *Chronic traumatic arthritis* with a development of synovial fringes (p. 754) produces in certain cases symptoms almost identical with those of a displaced cartilage, except that usually there is no history of sudden onset. The margins of the articular cartilages are usually thickened and characteristic, and the synovial villi and fringes can often be felt; the crepitus is different from that of a slipping cartilage; and the other knee may be similarly affected. The edges of the *retropatellar fatty pad* may be thickened and villus-like, and then may project backwards and get nipped between the ends of the bones. An enlarged subligamentous bursa may have a similar effect in pushing the pad backwards. The history in these cases is usually distinct from that of a torn cartilage, and the tenderness is not at the same spot. The diagnosis of a *loose foreign body* in a joint is referred to at p. 763.

Inflammation of a semilunar cartilage (*meniscitis*) also needs to be considered; it usually results from a heavy fall on the foot or heel, whereby the cartilage is bruised; painful limitation of movement results, and especially pain on standing, or straightening the knee, which is kept semiflexed; there are usually no sudden attacks of painful locking of the joint, but the cartilage is tender, and can perhaps be felt, though it is not movable.

The **Treatment** in the early stages consists in complete reduction of the displacement by manipulation, if need be under an anæsthetic. Unless the patient can extend the knee fully, some displacement persists, and subsequent trouble is sure to follow. Reduction of an internal cartilage is effected by flexing fully both the knee and hip joints; the leg is then everted fully, and abducted so as to open up the joint interspace on the inner side. A rapid movement of inversion and extension, combined with pressure on the back of the cartilage with the thumb, usually brings about satisfactory reduction, and complete extension is at once possible, and the full range of movements is restored.

Subsequent treatment consists in applying a firm pressure bandage to the knee, combined with rest, and later massage and electrical treatment will be required to tone up the quadriceps.

Should these methods of treatment fail, and the diagnosis of a torn or displaced cartilage be fairly well established, **operative treatment** is justifiable. The most minute precautions as to asepsis must of course be taken (p. 724). The patient's knee flexed to a right angle hangs over the end of the operating-table, and the surgeon may with advantage sit facing it and perhaps support the foot between his knees.

A curved incision sloping backwards is made by the side of the patella, or a transverse one along the upper edge of the tibia; the extent of the superficial incision is of no importance so long as the incision in the capsule is correctly placed. Alternatively, the incision illustrated in Figs. 420 and 421 may be used where a more complete exposure of the joint is advisable. This is made advisably with a fresh knife (to avoid possible contamination from organisms in the skin) between the inner edge of the patellar ligament and the internal lateral ligament, which must not be encroached on. The cartilage is now exposed, and its shape and mobility readily tested by picking it up on a blunt hook slipped under its free edge. Torn and partially detached fragments are easily seen and removed, and in cases of general mobility the whole cartilage can be excised by pulling on it from the front;

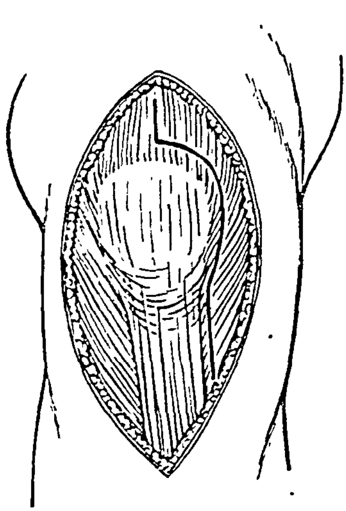


FIG. 420.—ILLUSTRATING INCISION USED FOR COMPLETE EXPLORATION OF THE KNEE-JOINT.

Curved incision through aponeurosis on the inner side of patella.

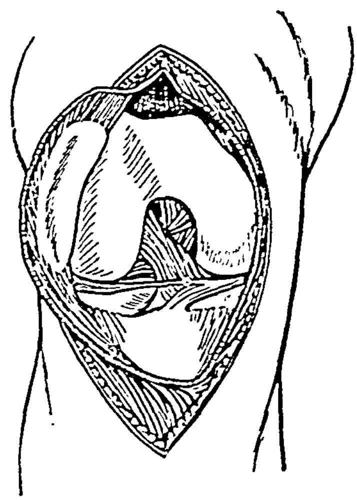


FIG. 421.—PATELLA AND LIGAMENTUM PATELLÆ DISPLACED OUTWARDS TO EXPOSE INTERIOR KNEE-JOINT.

care must be exercised not to leave tags projecting from the divided attachments, as they may cause trouble later on. The fringes are then explored, and the other cartilage; hæmostasis is effected, and the joint carefully closed in layers without drainage. It is kept quiet on a splint for two or three days, and then gentle movements are permitted; when the wound is healed, massage and movements against resistance are instituted, but the patient should not place his weight on the limb for ten to fourteen days at least. Careful exercises to improve the muscles of the limb are subsequently required.

Dislocations of the Ankle-Joint may occur in the following directions: *outwards*, *inwards*, *backwards*, *forwards*, and *upwards*, this being the order of their frequency. Owing to the fact that the astragalus is wedged like a block into the mortice formed by the lower ends of the

tibia and fibula, it is obvious that fractures of these bones are frequently met with as complications.

The **lateral** dislocations are in reality fracture dislocations, and have been already described in the chapter on fractures (p. 627).

Although the upper articular surface of the astragalus is broader in front than behind, dislocation of the foot **backwards** is a more common accident than displacement forwards. It results from falls on the feet while running or jumping, or by sudden violence applied to the limb when the foot is fixed. Usually both malleoli are fractured, and the articular surface of the astragalus is thrown behind the lower end of the tibia. The heel projects unduly backwards, and the articular surface of the tibia usually rests upon the neck of the astragalus, the scaphoid, or even the cuneiform bones.

Dislocation **forwards** is very uncommon, and may occur without any associated fracture of the bones of the leg. The foot is apparently lengthened, and the tibia rests upon the posterior part of the upper surface of the os calcis, behind the astragalus, the prominence of the heel and of the tendo Achillis being lost.

The **Treatment** of antero-posterior dislocations consists in reduction by traction, followed by immobilization, with the foot at right angles. The leg is flexed upon the thigh, so as to relax the tendo Achillis, or, if necessary, this structure is divided.

A dislocation **upwards** has been described in which the astragalus, together with the foot, is carried up between the tibia and fibula, owing to a rupture of the inferior tibio-fibular ligament and the lower end of the interosseous membrane, or a fracture of the tibia with displacement upwards of a wedge-shaped fragment. The deformity is very marked.

Dislocation of the Astragalus alone is by no means common. It consists in a partial or complete detachment of the bone from all its normal connections, both to the bones of the leg and of the foot, and its displacement from under the tibio-fibular arch. It may travel *backwards* or *forwards*, with or without lateral rotation, and be complete or incomplete. It is frequently more or less compound.

Dislocation **forwards** is much the more common variety, and is usually associated with partial rotation, the displacement occurring more frequently outwards than inwards. When complete, the bone is entirely detached from its connections, and lies upon the upper surface of the external cuneiform and cuboid bones, the skin of the dorsum being tightly stretched over it, or even torn.

In the incomplete variety, the head of the astragalus impinges either upon the scaphoid on the inner side, or the cuboid on the outer, whilst the lower end of the tibia rests on the posterior half of the articular surface of the astragalus.

Dislocation **backwards** is almost always complete, and may or may not be associated with rotation of the bone, which can easily be felt between the tendo Achillis and the malleoli. Fracture of one or both malleoli is almost certain to accompany this displacement.

Treatment.—Reduction is possible only in the incomplete forms of dislocation. The patient is anæsthetized, the knee flexed to relax

the muscles or the tendo Achillis divided, and traction upon the foot established, so as to enable the surgeon to apply pressure upon the displaced bone in a suitable direction. In the complete variety reduction is impracticable, owing to the fact that the os calcis is drawn up into contact with the malleolar arch. In such cases manipulation is useless, and excision of the bone is necessary. Comparatively little impairment in the function of the foot results from this operation.

Subastragaloid Dislocation.—By this term is meant a displacement of all the bones of the foot from below the astragalus, which retains its normal position between the malleoli. It is due to some violent strain or wrench of the foot. Displacement may occur either forwards or backwards, but in the great majority of cases it is either *backwards and inwards* or *backwards and outwards*. The luxation is rarely complete as regards the calcaneo-astragaloid joint, but the articular surfaces of the head of the astragalus and scaphoid are completely separated, the former structure lying on the dorsal surface of the latter bone. The foot is greatly deformed, the anterior portion being shortened, the heel projecting, and the toes pointing downwards. The head of the astragalus forms a rounded globular swelling under the tense skin. In a compound dislocation of this nature examined *post mortem*, the inner edge of the under surface of the astragalus had burst through the skin; the vessels and nerves were torn or stretched, and even when the wound in the skin had been enlarged reduction was impossible owing to the tendons which were caught around the neck of the astragalus. In such a case removal of the astragalus would have been the only practicable treatment.

In the **inward** displacements, the foot is somewhat inverted, so that the outer malleolus is unduly prominent, and the inner malleolus is lost in a deep depression caused by the lateral displacement of the os calcis; the foot is thus in a position somewhat simulating talipes equino-varus. In the **outward** dislocations the foot is everted, the inner malleolus prominent, and the outer buried, a position of talipes equino-valgus being thus assumed. In both forms the tendo Achillis is curved, with its concavity towards the displacement. **Treatment** consists in reduction by manipulation, which is sometimes readily accomplished, but may be a matter of the greatest difficulty, probably from the tibial tendons becoming hitched around the neck of the astragalus. Section of the tendo Achillis is occasionally needed. In difficult cases excision of the astragalus may be required, and when there is much associated injury to the soft parts amputation.

CHAPTER XXIII.

DISEASES OF JOINTS.

General Considerations.—A careful study of the anatomy and physiology of joints is required in order to appreciate the many problems, mechanical and pathological, which confront the surgeon in the treatment of their diseases. Limitations of space prevent us from discussing these, but we would remind students that the exposed ends of the bones entering into a joint are covered with articular cartilages, which in young people are separated from the shafts by the intervention of epiphyses, and these protect the joint in many cases from the spread of disease from the diaphyses, but in some cases are a source of danger in that the junction cartilages are intra-articular, *e.g.* in the hip-joint. Holding the bones together is a complicated series of ligaments, of varying strength and density, usually inserted into the epiphyses in young people, and arranged so as to resist the various forms of strain to which the particular joint is exposed. Lining the under side of the ligaments, and more or less closely attached to them, is the synovial membrane, a thick, smooth structure which secretes a glairy fluid for lubricating purposes; it extends as far as the margins of the articular cartilages. Where it is not in close proximity to the ligaments, as in the knee-joint, the interspaces are padded with fat, which may occasionally prove a source of trouble. On the inner aspect of the membrane are a number of small villi, which sometimes develop to a considerable size.

Inflammatory affections of joints are of the most diverse character, and are brought about by injury, infection, or general constitutional conditions, such as gout. The trouble may be limited mainly to the synovial membrane, constituting merely a **synovitis,** or may spread to and involve other articular structures, such as ligaments, cartilages, ends of the bones, etc., thereby constituting an **arthritis,** but there is no absolute line of demarcation between the two.

Effusion into a joint occurs in most of the various manifestations, the exudate varying with the cause. The phenomena, however, are similar in all the diverse conditions, and it would be well to note them here. *Shoulder :* The curvature of the shoulder is increased, and the deltoid expanded by a fluid swelling beneath it, which is especially noticeable at its anterior border along the bicipital groove, and sometimes posteriorly; in the axilla a painful intumescence may also be felt. These symptoms may be somewhat simulated by inflammation of the multilocular subdeltoid bursa, but the latter condition is recognized by the absence of any axillary swelling, by its not encroaching on the anterior and posterior borders of the deltoid, and by the fact that, although when the patient voluntarily moves his arm

pain is produced, yet when the surgeon gently manipulates it, so as to press the head of the bone against the glenoid cavity, there may be none.

Elbow: The arm is maintained in a position of flexion and pronation; the hollows on either side of the olecranon and tendon of the triceps are replaced by soft fluid swellings, the outer of which also extends down to, and masks, the head of the radius; there is usually a little general puffiness in front of the joint. It is readily distinguished from inflammation of the olecranon bursa by the fact that in the latter condition there is a central fluid prominence over the bone, whilst in the former the swellings are placed on either side of and above the bony projection.

Wrist: The hand is in a condition of slight flexion, and there is a general fulness around the joint, most marked on the anterior and posterior aspects, but also noticeable below the styloid processes. The tendons in their sheaths are lifted up back and front, and deep fluctuation may be detected beneath them. It is distinguished from a teno-synovitis by the facts that the swelling is limited more or less to the joint line, and does not extend up and down in the direction of the tendons; there is also no limitation of movement of the fingers, and the characteristic crepitus of teno-synovitis is absent.

Hip-joint: Effusion cannot be easily detected by digital examination. There may be a little fulness and tenderness in the gluteal region, or in the upper and outer part of Scarpa's triangle. The most characteristic feature, however, is the position of flexion, abduction, and eversion taken by the limb, whilst limitation of movement is equally marked.

The *Knee*, when distended with fluid, presents a rounded outline, in which all the normal hollows, especially those on either side of the patella and ligamentum patellæ, have disappeared. There is also a swelling corresponding to the subcrural pouch, more marked on the inner than the outer side, and extending for 3 or 4 inches above the patella. Fluctuation can be readily detected when one hand is placed above the patella, and the fingers of the other hand compress the tissues on either side of the ligamentum patellæ below, or by alternate pressure on either side of the rectus tendon. When the effusion is considerable the patella is felt to float, and on pressing it sharply backwards can be made to tap against the intercondyloid notch of the femur (*patellar tap*). A smaller effusion is recognized by pressing the fluid downwards from the subcrural pouch with the knee fully extended, when the patellar tap can usually be demonstrated. Enlargement of the bursa patellæ is recognized by the swelling being central and in front of the patella, so that its outline is obscured.

Ankle: The foot is held in a position of slight equinus, and the hollows between the tendo Achillis and the malleoli are replaced by fluctuating swellings, whilst the dorsal tendons are displaced forwards, and a fluid swelling appears in front of each malleolus. Enlargement of the bursa beneath the tendo Achillis is so obviously confined to the back of the joint that it should never be mistaken for true synovitis of the ankle.

The position to be adopted in the treatment of inflamed joints is a most important matter and must be carefully noted. It may be termed for convenience the **Position of Rest,** and is such as not only gives comfort to the patient, but also ensures that if the joint should become fixed, the maximum of utility is secured for the limb. Each joint must be separately studied.

Shoulder : The arm may simply be bandaged to the side if there is but little likelihood of subsequent stiffness; but whenever ankylosis is possible, it should be fixed at an angle of about 40 degrees away from the side. This permits later of a much greater range of usefulness, inasmuch as it utilizes the scapular movements. Fixation with greater abduction than this prevents the arm being placed to the side, as there is only a limited range of scapular movement.

The *Elbow* (which of course includes the superior radio-ulnar joint) is placed on an internal angular splint and flexed to a little more than a right angle, so that the hand can be approximated to the mouth. The palm of the hand must be turned slightly upwards, *i.e.* so that the patient can just see into it. Before allowing the joint to become fixed in this position, however, it is well to ascertain from the patient what his work is, and what position of the arm will be most useful to him, as this varies much. If both elbows are threatened with stiffness, one should be kept in a position of flexion to a little more than a right angle, the other to a little less. In a person whose occupation is clerical, it may be best to allow fixity of the left forearm to occur in a position of pronation, so as to enable him to hold papers down to the table when writing.

The *Wrist* must always be immobilized in a position of slight dorsiflexion, so as to improve the power of grasping. When possible, the fixation should not include the fingers; if it is necessary to place them on a splint, movements must be maintained by giving them a full range each day. It is wonderful how quickly adhesions form in the small joints of the fingers and in tendon sheaths when prolonged fixation of the fingers is associated with septic changes in the wrist or arm.

The *Hip* is best immobilized in a position of moderate flexion (35 degrees) and slight abduction, so as to counteract the pull of the powerful adductors, which are always liable to adduct and invert the limb. A careful watch must be kept on the patient's pelvis, to make sure that it has not been tilted by muscular action, so as to bring about once again a position of adduction; this warning is especially necessary in reference to children. A Thomas's splint usually suffices to secure this position, but in children a double Bryant with extension to both legs is sometimes desirable.

The *Knee* is usually kept in full extension, but there is no question that the most convenient position for permanent fixation is one of slight flexion, as this assists in mounting stairs and in sitting. A shaped back-splint will suffice in milder cases, but in the more severe a Thomas's splint is required.

The *Ankle* should be kept with the foot at right angles to the leg, and this can be obtained by placing the limb on a Macintyre splint.

Finally, it must be noted that although joints are now known to

possess a considerable power of resistance to infection by pyogenic organisms, yet any breach of strict aseptic precautions is only too likely to be followed by disastrous results, endangering both the utility of the limb and also the life of the patient; hence the most minute care must be taken in all **operations which involve the opening of joints.** Very thorough sterilization of the skin must be insisted on, and fingers should never be introduced into the wound. A fresh knife should be employed to open the synovial membrane, for fear that in passing through the skin the knife may have been contaminated. No antiseptics are allowed to enter the joint, as they are always somewhat irritating, and may cause a considerable synovial effusion which becomes a suitable nidus for the development of bacteria, if such happen to be present. At the conclusion of the intra-articular manipulation, the joint should be gently irrigated with hot saline solutions so as to remove blood-clots, and carefully closed by buried sutures, which involve *seriatim* the synovial membrane, the ligaments, the overlying muscular or aponeurotic structures, and finally the superficial parts; exact co-aptation of each of these structures is necessary if good functional repair is to be obtained free from weakness. Drainage is most undesirable, and the technique must always aim at avoiding the use of a tube; but if there has been much bleeding, it may be advisable to place a drainage-tube *down to, but not into,* the joint cavity for twenty-four hours. The limb is usually kept at rest for a few days, perhaps on a splint, and then movements are cautiously permitted, at first passive, then active, and finally active against resistance, and all these advisably before the patient strains the joint (if a knee) by bearing upon it the weight of the body. Massage to the surrounding muscles will of course be employed as soon as the wound is securely healed.

Traumatic Synovitis is the condition which follows such injuries as strains or sprains, and is characterized by an effusion of blood and synovial fluid within the joint cavity, and by pain on any movement which stretches the injured part. The characteristic signs of effusion into the particular joint are manifested, but inasmuch as the exudate is aseptic, it is quickly absorbed, granting that the joint is kept at rest. Some of the blood which escapes into the joint clots, and the coagula may collect in the reflections or pouches of the cavity, or may become fixed to the raw tissues exposed by the tear in the synovial membrane. These coagula are not always readily absorbed, but are organized into fibrous tissue, constituting adhesions which may limit the free movement of the limb.

If the condition is not treated effectively by suitable rest in the early stages, the tear in the synovial membrane may be opened up again and again, leading to recurring attacks of synovial effusion (the so-called chronic synovitis, *q.v.*) with relaxation of ligaments and increasing disability. On the other hand, too prolonged fixation may result in stiffness due to the formation of adhesions and atrophy and loss of tone of muscles. **Treatment** must therefore be a judicious combination of rest and movement. In the early stages rest must be employed for a few days in order to secure absorption of the exudate;

the position of rest already alluded to must be adopted. It may not always be necessary to immobilize the joint on a splint, but at any rate it must be well supported by pressure exercised by a firm bandage over a pad of cotton-wool.

As soon as the effusion has disappeared, the joint should be strapped and fixed in such a position as shall approximate and keep at rest the damaged tissues. Union will be secured in seven to ten days to such a degree as to permit of gentle active movements and a greater range of passive movement, but these must never be pushed at this stage to the point of causing obvious pain. Practitioners must remember that one full range of movement up to the limit of painlessness in the course of the day is all that is required to ensure against subsequent stiffness; repeated 'sawing' movements of a joint only irritate it, and may do harm rather than good by stretching unduly or tearing the new bond of union. Patients should never be allowed to place any strain on a limb after an attack of synovitis without support; this may be given by elastic pressure, or by a crepe bandage over cotton-wool. Massage is useful to maintain the tone of the muscles and to assist in the absorption of the exudate, but must be employed with discretion, and cannot take the place of active exercise. Should the effusion persist, assistance may be gained by the alternate applications of hot and cold water, and by rubbing with stimulating embrocations.

Pyococcal Infection of Joints.

It is now well recognized that most cases of acute synovitis of joints are associated with the presence of pyococci, which are derived from the blood. It has also been abundantly shown that penetrating wounds associated with the presence of pyococci are not invariably destructive, and rightly handled there is much defensive power in the synovial membrane. On the other hand, if the inflammatory trouble progresses beyond certain limits, it results in the gravest destructive manifestations and threatens both life and limb. It is obvious that the pyococcal infection of a joint may result in many types of inflammatory trouble, but for descriptive purposes it is convenient to describe three varieties, which may be merely stages in one case, or to which the trouble may be limited.

The **organisms** present vary necessarily with the cause. Non-penetrating wounds are likely to be infected by some particular organism derived from elsewhere in the body, *e.g.* it may be secondary to pyorrhœa, impetigo, carbuncle, tonsillitis, scarlet fever, or be dependent on gonorrhœa. In many cases it is impossible to find the causative lesion, although one looks for it carefully. In penetrating wounds (nails, knives, gunshot wounds, etc.) the infection is often of a mixed type, and in military work anaërobes are often present. Of particularly grave prognosis is a hæmolyzing streptococcus.

I. Acute (Non-Suppurative) Synovitis.

In this affection the inflammation is limited almost entirely to the synovial membrane, the ligaments and other structures of the joint being but little affected. It is sometimes attributed to cold or injury,

the organisms reaching the joint from the blood, as is also the case in the milder pyæmic and gonococcal affections, and some so-called cases of rheumatism.

Pathological Anatomy.—Acute synovitis is characterized by hyperæmia of the synovial membrane, and exudation of plasma and leucocytes firstly into the substance of the membrane, causing it to be thickened and spongy, and subsequently into the joint; the endothelium also proliferates, and is shed. In the early stages the effusion consists of synovia, diluted with blood-plasma, and often discoloured with blood in traumatic cases, and hence on removal is sometimes spontaneously coagulable; after a time the plasma may coagulate, depositing lymph upon the articular surface, whilst serum remains. This lymph may either be removed by a natural process of absorption when the inflammation comes to an end, or it may become organized, so as to form adhesions, which consist of loose fibro-cicatricial tissue containing a few delicate blood-vessels and covered with endothelium from adjacent serous surfaces. In some varieties, especially if repair is not quickly established, a certain amount of perisynovial inflammation follows, resulting in congestion, infiltration, and perhaps relaxation of the ligaments.

The **Clinical Signs** of acute synovitis consist in the joint becoming painful and distended, and in the case of superficial joints hot to the touch and even red. The limb is maintained by muscular spasm in that position which gives the most ease, *viz.* that in which its capacity is the greatest, and this is usually one of slight flexion. If the condition is neglected, the flexion may increase considerably, and the limb become more or less fixed in an undesirable position, whilst the muscles governing the movements of the joint undergo rapid atrophy. The phenomena resulting from effusion into various joints have been already noted (p. 721).

When the acute stage has passed, the joint is usually left in a weak and relaxed condition, with a little passive effusion, or perhaps some adhesions. The adhesions which follow acute synovitis are usually slight in character if the case has been properly treated, and extend between opposing surfaces of synovial membrane or bone. The characteristic signs of such a condition are definite limitation of movement in some particular direction, and possibly a little soft crepitus; no pain is experienced until tension is put on the adhesion.

The **Treatment** of acute synovitis consists in immobilizing the limb in the position of rest (p. 723); and necessarily, in all severe cases, the patient must be confined to bed. In the early stages cold should be applied to the joint by means of evaporating lotion, an icebag or Leiter's tubes, but this is not advisable in old people; in the later stages fomentations give greater relief. When the distension is considerable, removal of some of the fluid by a carefully purified aspirator or syringe will diminish pain and hasten recovery. Such fluid should always be examined bacteriologically, and if organisms are found the joint should be washed out with normal saline solution and treated as described below (p. 728). In not a few cases of acute synovitis

the induction of passive hyperæmia by the application of an elastic bandage will give relief and hasten repair.

In the subacute stage, when the joint is weak and relaxed, massage or friction with stimulating liniments should be employed, whilst in the later stages elastic pressure is often of the greatest value. If the case has been neglected and the limb has assumed a vicious position, the patient should be anæsthetized and the deformity corrected; or gradual extension is made by means of a weight and pulley until a correct position is attained.

If the movements of the joint are limited by the presence of **adhesions,** these must be broken down under full anæsthesia. It is not always easy to select the cases which require this treatment, and in which it will be beneficial. In this connection the following points should be remembered: (1) Limitation of movement due to a general arthritis, however mild, is characterized by pain in every direction; with adhesions suitable for breaking down there is a certain degree of painless movement, and pain only commences when this is exceeded, and the adhesions are stretched. (2) Massive adhesions, such as those which form after serious inflammatory trouble, hold out little prospect of improvement by wrenching (except for the correction of deformity), as the divided surfaces have to heal, and in so doing fresh adhesions form. (3) The time for breaking down adhesions is as soon as possible after the inflammatory trouble has ceased, as evidenced by cessation of pain and reduction of swelling. Delay only means increased strength of the adhesions, and increased atrophy and want of tone of muscles. (4) The actual breaking down of the adhesions should be accomplished by steady force, and not by intermittent jerks. In the less serious cases, a full range of movements should be aimed at from the first, and the freedom of all movements of the joint should be tested. In the graver cases it may be desirable not to do too much at a time, as a good deal of reaction often follows; the manipulation may be repeated more than once. (5) When it is likely that a good deal of force will need to be employed, it is wise as a precautionary measure to place splints on the limb above and below the joints, since it is not difficult to break one of the bones. (6) The joint is kept at rest for a day or two after the manipulation, but once at least each day the limb should be put through a full range of the movements secured. (7) As already pointed out, no attempt should be undertaken to break down adhesions in a joint in the neighbourhood of septic sinuses; intra-articular hæmorrhage followed by suppuration is only too likely to follow.

II. Acute Suppurative Synovitis (or Empyema of Joint).

This condition is in reality merely a further stage of that just described; the effusion becomes at first turbid by the admixture of pus cells with the synovial exudate, but finally it becomes frankly purulent. For a time it is quite possible for the suppurative process to be limited to the synovial membrane with a certain amount of perisynovial infiltration, but no true spread beyond the capsule or

destruction of the articular cartilage. This stage proves most amenable to judicious treatment; but it is not uncommon to see cases of this type run over into an acute destructive arthritis, sometimes as a result of mismanagement, at others in consequence of the virulence of the causative organisms.

Causation.—(i.) Every septic penetrating *wound* of a joint passes through a stage of suppurative synovitis, and if hæmolyzing streptococci are absent, if the patient's resistance is fairly good, and if he is correctly treated, the condition may not progress beyond this. This statement is equally true of post-operative infection. (ii.) It may arise in a manner exactly analogous to that in which acute infective osteomyelitis is produced, *viz.* by *auto-infection.* A slight injury, *e.g.* a sprain or strain occurring in a wealky child, convalescent from measles or scarlet fever, may result in this affection, which is then commonly due to the pneumococcus. Traumatism in a patient riddled with sepsis, *e.g.* the breaking down of adhesions in a joint, particularly if in the neighbourhood of septic sinuses and diseased bone, is almost certain to be followed by suppuration in the joint, which becomes distended with blood and pus. (iii.) It may be produced by the lodgment of a pyæmic *embolus*, and in a similar way it not unfrequently follows as a sequela of fevers, such as enteric or pneumonia, by direct transmission of some infective material. (iv.) It is sometimes met with as a result of *gonorrhœa* (p. 725). (v.) It may be lighted up as a result of the *extension* of inflammation from the end of a neighbouring bone, or from the bursting of a subcutaneous or bursal abscess into the joint. Acute arthritis of the hip-joint is sometimes due to the former of these conditions, being consecutive to an acute infective osteomyelitis of the upper end of the femur.

The **clinical signs** are merely those of a hyperacute synovitis. The joint is swollen and distended with fluid; it is hot to the touch and tender; movements, even the slightest, are often extremely painful; and sleep becomes difficult, as the relaxation of muscles associated therewith means a change of position of the limb, which involves pain and wakes the patient. There is almost always a certain degree of pyrexia, though usually not excessive.

The **Treatment** of these cases is based on the recognition of the protective and defensive power inherent in the synovial membrane if correctly handled; in other words, the synovial membrane conforms in its reactive power to that of other serous membranes, such as the peritoneum and pleura. To be effective, treatment must be early, and the essential elements are to remove the exudate, to irrigate the cavity, perhaps to introduce some antiseptic, and to close the joint once again, trusting to the membrane to do its own defensive work. The limb is of course suitably immobilized, and slight extension applied.

The removal of the exudate may be effected by a syringe or by trocar and cannula, but it is probably wiser in most cases to cut down on and expose the synovial membrane, which is then picked up by tissue forceps and opened sufficiently to give exit to the discharge, and to enable a small tube or catheter to be introduced for irrigation purposes. The knee is approached from either side, but preferably

from the outer; the shoulder-joint from the front along the bicipital groove; the hip from the front between the tensor fasciæ femoris and rectus muscles; the ankle from either in front of or behind the malleoli, avoiding carefully the tendon sheaths; the elbow by the outer side of the triceps tendon.

Irrigation of the joint cavity must be effective; normal saline solution is all that is necessary, but some surgeons prefer an antiseptic, such as flavine (1 in 1,000) or Dakin's solution. If any fluid is to be left in the joint, either a 2 per cent. solution of formalin in glycerine or a 1 in 1,000 solution of flavine should be employed; about one ounce of each will be required for a knee-joint. If the effusion recurs, this process may be repeated more than once.

Under no circumstances must a drainage-tube be introduced into a joint in this condition; it is certain to determine ankylosis, and the surgeon's aim and object is to secure a movable joint.

The limb is placed in the position of rest, but some slight extension is applied so as slightly to separate the articular surfaces and thereby limit pain as well as check muscular spasm. The extension must be only slight, as the ligaments are always liable to be softened to some degree and may become relaxed. In dealing with a knee, for example, an adhesive plaster extension is applied to the limb under an anæsthetic; the joint is opened, irrigated, and, if thought desirable, injected. A Thomas's splint with side-bars hinged opposite the knee is put on; suitable extension is arranged, and the splint is suspended from a Balkan frame.

The great majority of cases treated in this way will quiet down; the temperature falls; the pain diminishes, and the swelling disappears. The surgeon must now turn his attention to *mobilization* of the limb. If this is undertaken rashly and too rapidly, the joint 'flares,' indicating that the bacteria in the joint are not destroyed, but merely that their activity is suspended; any injudicious stimulation gives them a fresh opportunity for evil.

When the inflammatory trouble has apparently ceased, the knee is cautiously and gently bent to an angle of about 10 degrees, and the extension replaced; if there is no reaction, a larger range is given on the following day, and still more day by day. After about a week the hinges of the splint are daily relaxed for a time, and the patient permitted and encouraged to move his knee actively within limits which can rapidly be increased; often in three to four weeks a full range of movement is possible. Massage of the muscles of the limb will assist in this restoration of function.

Not unfrequently, however, a joint 'flares,' even after a slight degree of movement cautiously regulated. It is then kept at rest for a day or two, and the inflammatory reaction will probably subside; possibly the patient's general condition will be improved by this attack, which is in reality an auto-vaccination. The next time movement is allowed the reaction will probably be less, and then the ordinary course outlined above may be followed out.

Should the patient come under observation late, or should irrigation fail to check the inflammatory trouble, or should the 'flare-up' after

a preliminary or late movement be severe, more active measures must be taken if an acute destructive arthritis is to be prevented. Free incisions must be made into the joint so as to give satisfactory drainage, *e.g.* for the knee an incision on both sides of the patella upwards to lay open the suprapatellar pouch; for the elbow, on either side of the olecranon tendon; for the shoulder, along the bicipital groove. Here, too, the rule must be adopted: *No drainage-tube in the joint.* The incisions are left widely open, and the joint cavity irrigated occasionally; the essential element is to urge, and if need be coerce, the patient into moving the joint actively, however painful it may be. No means of drainage is more effective than active movement, which squeezes out the pus from the synovial cavity. After a short time the movements become comparatively painless; the joint heals up, and movement is retained. There is no doubt as to the value of this method in cases of suppurative synovitis.

Of course, when the inflammatory trouble has ceased and the wounds have healed, the patient is not allowed to put weight or strain on the joint without suitable support or until the muscles have been restored to tone by massage and re-educational exercises.

III. Acute Suppurative Arthritis.

In this condition the inflammatory process involves all the elements of the joint, synovial membrane, ligaments, cartilages, and bones, and may spread widely along muscle planes, or along the medullary cavity. It is associated with great suffering and constitutional disturbance, and endangers both life and limb.

For **Causation**, see p. 728.

Pathological Anatomy.—The *synovial membrane,* at first merely infiltrated and hyperæmic, soon becomes converted into granulation tissue, exuding an abundance of pus. The organisms spread through the perisynovial cellular tissue to the *ligaments,* which become sodden and relaxed by the presence of a sero-plastic exudate between the fibres, rendering them soft and œdematous, so that the tonic contraction of the muscles easily stretches them and brings about displacement. The *articular cartilages* are disintegrated and destroyed in various ways according to the acuteness of the inflammation and the amount of pressure to which they are exposed. In acute cases they early lose their normal bluish-white appearance, and become opaque and slightly yellow. The central parts, which are exposed to pressure between the ends of the bones, soon disappear, possibly by the activity of the tryptic ferment in the exudate, whilst the peripheral portions are eroded by the overgrown granulation tissue developing from the synovial membrane. When once the cartilage has been perforated at any one spot, the suppurative inflammation spreads along its under surface, stripping it from the bone, and thus inducing necrosis, as a result of which isolated portions of dead cartilage may be found lying in the joint. The *interarticular cartilages* are affected in a very similar manner, and quickly disappear. The *ends of the bone* pass into a condition of acute osteitis, resulting in the transformation of the

medulla into granulation tissue, absorption of the bony cancelli, with or without suppuration, and sometimes necrosis of small portions of the cancellous tissue (*caries necrotica*). The veins within the cancelli become thrombosed, and hence pyæmia may result. The *periosteum* covering the ends of the bones is also inflamed and hyperæmic, in consequence of which spiculated or stalactitiform osteophytes are produced (Fig. 422). The *muscles* in the neighbourhood of the joint undergo rapid atrophy and fatty degeneration.

FIG. 422.—ENDS OF THE BONES AFTER ACUTE ARTHRITIS OF ELBOW, SHOWING THE CARIOUS SURFACES DEVOID OF CARTILAGE, AND THE DEVELOPMENT OF STALACTITIFORM OSTEOPHYTES.

Course of the Case.—In the early stages acute arthritis manifests itself as a hyperacute synovitis, combined with severe pain and fever. The pain is often so intense that the patient cannot bear the part to be touched or the bed shaken, and, indeed, the slightest jar of the limb is so exquisitely painful that the patient may scream with agony. The joint itself is distended with a turbid effusion, which rapidly becomes purulent, and the tissues around are hyperæmic and œdematous. The patient naturally places himself in that position in which the limb obtains the greatest ease, and therefore usually semiflexes the joint and fixes it by muscular contraction.

As the disease progresses the tension within the capsule increases, until in time it yields, and the pus either travels directly to the surface, or burrows deeply into the substance of the limb, and spreads along the muscular planes; thus, in the knee an enormous abscess may collect beneath the vasti muscles, stripping them from the bone for a considerable distance. The pain increases whilst the abscesses are forming, and becomes especially distressing at night, the patient being often waked by a painful start just as he has fallen asleep. This condition usually indicates that the articular cartilages are becoming affected, and is explained by the fact that just as the patient loses consciousness the muscles which fix the joint are relaxed, and allow the inflamed surfaces to shift their position slightly, exciting severe pain and a sudden spasmodic contraction of the muscles. Gradually the deformity becomes more and more obvious, whilst the infiltration

and relaxation of the ligaments sometimes allow of abnormal movements, *e.g.* of lateral mobility in the knee-joint; the ends of the bones become carious, and absolute displacement or dislocation may follow. Sinuses may open in all directions, and the patient suffer from recurrent rigors, caused by toxæmia or the onset of pyæmia. The constitutional effects are always severe, consisting of high fever, and rapid exhaustion from the pain, sleeplessness, and absorption of toxins.

The *terminations* of this affection are as follows: (*a*) Recovery, rarely with a movable joint, and then only after early and active interference; in most cases ankylosis in a good or bad position, according to the treatment, is the best result that can be expected. (*b*) During the acute stage the patient may die of pyæmia, or acute toxæmia and exhaustion. (*c*) If he survive the acute stage, chronic suppuration may ensue, and symptoms of hectic fever and amyloid degeneration of the viscera may supervene. In such cases sinuses leading down to carious bone exist, and, unless efficient measures are taken to drain the parts or to remove the diseased structures, perhaps by amputation, the patient is likely to die from exhaustion or chronic toxæmia.

The **Treatment** already described as suitable for a suppurative synovitis is initiated in the first place. The limb is immobilized in the position of rest (p. 723); extension is applied to keep the inflamed bone ends apart, but with as little force as possible, so that the infiltrated and softened ligaments shall not be unduly stretched; suspension of the limb is also most necessary. If irrigation fails to check the inflammatory process, and increasing œdema of the peri-articular region and limb indicates that the trouble is extending, the joint must be laid open and free drainage secured.

Small incisions with a view to introduce drainage-tubes are of little value; long incisions opening up the whole joint cavity must be employed. When all hope of gaining a movable joint has disappeared, drainage-tubes or strips of rubber glove may be employed, or continuous irrigation utilized; the Carrel-Dakin treatment is sometimes valuable in this connection. A keen watch must be kept on all aspects of the limb, so that the development of fresh abscesses may be detected and treated at once. A vaccine may possibly be prepared from the pus and administered. The fixation of the limb is carefully maintained and the general condition attended to. Irrigation continues until all signs of inflammation, heat, pain, and all startings of the limb, have passed away. The wounds are then allowed to granulate and the limb to consolidate. Chronic sinuses may persist for a time, leading to undrained pockets of pus or to diseased bone, which must be dealt with in an appropriate manner.

Excision is occasionally required early in the case in order to secure effective drainage, as in the shoulder, or more generally, at a later date, to prevent or remedy faulty ankylosis, or to place the limb in a good position; it is also sometimes used in cases of chronic suppuration with caries of the ends of the bones and displacement, but as a rule this is deferred until the wound has healed and all active trouble ceased.

Amputations may be needed for severe toxæmia or pyæmic symptoms threatening life, or for exhaustion from chronic sepsis, or for hopeless deformity.

Acute Arthritis of Special Joints.

In the **Shoulder,** infection sometimes occurs through the axilla, where the capsule is weak and easily invaded by organisms, as after an axillary cellulitis; more frequently it follows a penetrating injury. Severe pain is caused by any movement of the arm affecting the joint, and if abscesses form, they will come to the surface in front of or behind the deltoid, or in the axilla. It may suffice to open the articulation anteriorly, and irrigate it; but, if necessary, a counter-opening should be made behind by cutting down on a pair of dressing-forceps pushed backwards through the capsule. In many instances the patient's condition will not improve until the head of the bone has been excised, and then the subsequent results as regards movement and power of the arm are, on the whole, satisfactory.

In the **Elbow** there are no points requiring special mention as to clinical history or results, although it must be remembered that the superior radio-ulnar articulation is necessarily involved, and hence the power of pronation and supination of the hand is threatened. As to treatment, incisions should be made on either side of the olecranon, the ulnar nerve being avoided. The limb is then placed on a rectangular splint, *e.g.* Sir R. Jones's flexed arm splint, which permits of extension; the hand is placed midway between pronation and supination. In an adult excision may be undertaken as soon as the acute stage has passed, in order to obtain a movable elbow; but in children, where the growth is incomplete, it is better to allow ankylosis to occur, and excise, if need be, at a later date.

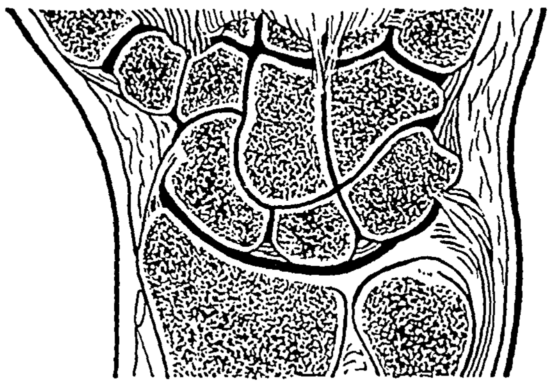


FIG. 423.—SECTION OF WRIST-JOINT TO SHOW THE DIFFERENT CARPAL JOINTS IN RELATION TO IT.

The **Wrist** may be infected secondarily to septic conditions following operations on ganglia in the neighbourhood or through direct injury, the various carpal joints soon becoming infected owing to their anatomical arrangement (Fig. 423). The essential treatment consists in free incisions parallel with the tendons, and avoiding the sheaths. Ankylosis usually results, and excision is not resorted to except when the disease has become very chronic, with extensive caries of the carpus (Fig. 424).

Acute arthritis of the **Hip-joint** is usually a sequela of acute infective osteomyelitis attacking the upper end of the shaft of the femur, and involving the joint, owing to the epiphyseal cartilage being intra-

capsular; it also results from pyæmia, and from penetrating injuries which in civilian life are rare. The symptoms are similar to those of the first stage of ordinary tuberculous disease (p. 771), but much more acute. There is high fever, together with intense pain, marked flexion and eversion of the limb, early suppuration, and rapid disorganization if not properly treated; indeed, where nothing is done, and the patient lives long enough, the head of the bone may be entirely absorbed, or is detached, and remains as a sequestrum in the disorganized articular cavity. As soon as the capsule gives way, the pus may come to the surface in any of the usual localities for hip-joint abscesses, and the limb then becomes inverted and adducted; spontaneous dislocation follows, and the head of the bone, or what

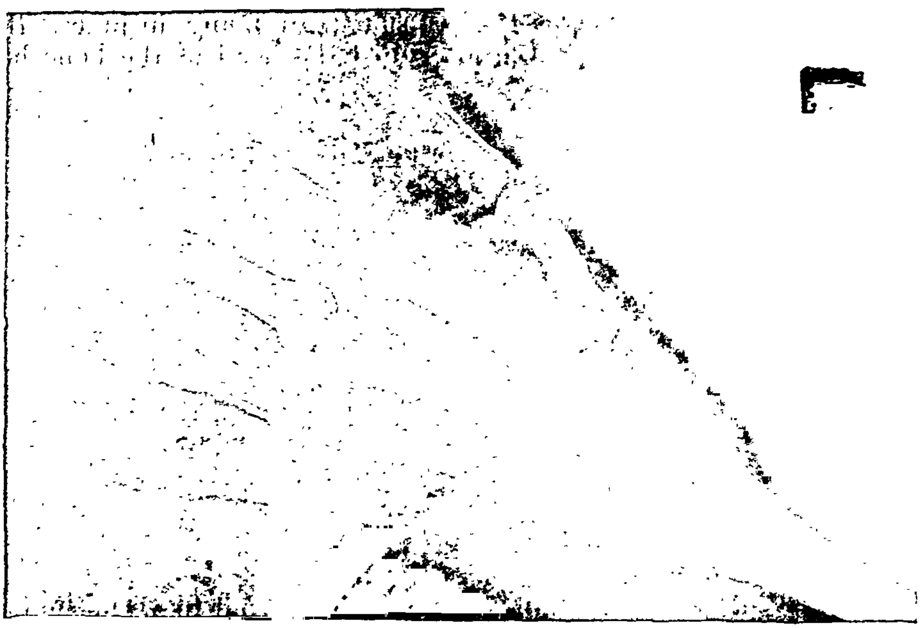


FIG. 424.—TUBERCULOUS DISEASE OF THE WRIST-JOINT.
Note the marked atrophy of the carpus with general blurring of the bones and narrowing of the joint spaces.

remains of it, travels upwards and backwards on the dorsum ilii. In treating these cases, the joint should be freely laid open in the situation which appears most favourable. The anterior incision is more suitable for the early, and the posterior for the later, stages, when the head of the bone is either dislocated, or remains *in situ* and separated from the shaft. A double opening may sometimes be utilized with advantage.

The **Knee-joint** is more frequently involved by this disease than any other, and is usually infected from without. The symptoms are exceedingly typical: the pain is very acute, and the joint hot and distended to its utmost capacity, the limb lying semiflexed and on its outer side. Left to itself, the capsule gives way, and suppuration rapidly extends upwards beneath the vasti, giving rise to large ab-

scesses, which ultimately find their way to the surface. The deformity gradually increases, until in the worst forms the tibia slips behind the condyles of the femur, the leg is flexed to a right angle and rotated outwards, and if the limb has long rested on its outer side, considerable lateral displacement may also occur. Early and efficient treatment (p. 726) will usually prevent such a disaster. If this fail, the joint should be freely incised on each side of the patella, so as to open up the subcrural pouch, and the whole articular cavity well washed out. In severe cases counter-openings must be made behind so as to drain the posterior pockets of the synovial cavity. A sinus forceps is introduced from the front, and passed backwards on either side so as to project posteriorly, and the point then cut down on. Possibly a drainage-tube may be employed with advantage, reaching as far as, but not projecting into, the synovial cavity. The nerves and tendons of the popliteal space must of course be carefully guarded. In these severe cases it may be wiser, however, to lay the joint freely open from the front by a wide U-shaped incision, dividing the ligamentum patellæ and turning up that bone. By flexing the leg completely, the femoral condyles can be exposed sufficiently to enable their posterior rounded ends to be removed by a vertical saw-cut. Plenty of room is thereby secured for the insertion of drainage-tubes from either side or for irrigation purposes. The anterior flap can be replaced and sutured in position.

When the **Ankle-joint** is involved, amputation has often to be resorted to, in consequence of the difficulty of securing good drainage, although excision of the astragalus will sometimes cut short the disease and lead to a good result.

Special Forms of Synovitis and Arthritis.

Pyæmic Synovitis is due to embolic infection from some suppurating focus. The joint becomes rapidly distended with pus, and often without pain. If the joint is promptly tapped or opened and irrigated, it usually does well, at any rate if the patient's vitality is fairly good; but if treatment is delayed, disorganization may follow (*vide* Pyæmia, p. 77).

Typhoid Disease of Joints occurs either as a synovitis or arthritis, and is due to a blood infection with the *B. typhosus*, either alone or in conjunction with pyogenic organisms. If purely typhoid in type, suppuration does not occur; there may be a mild synovitis in several joints, or a marked effusion in one followed by relaxation of ligaments, so that spontaneous dislocation may occur; this is most marked in the hip-joint. The prognosis is favourable in these purely typhoid lesions if deformity is prevented; effusion in excess is treated by aspiration or tapping, and washing out; a recurrence may require drainage. If pyococci are present, either alone or together with the typhoid bacilli, suppuration develops and masks the typhoid element. The routine treatment of a suppurating joint is required.

Pneumococcal Arthritis.—In the course of an acute pneumonia the pneumococcus is occasionally disseminated through the body, and is then very likely to attack a joint which has been already damaged,

giving rise to a suppurative arthritis with an effusion of thick creamy pus, or sometimes to a milder form of synovitis. Males are more often affected than females, and the upper rather than the lower extremity. Occasionally more than one joint is involved, and, with the exception of the hip, the larger joints are attacked rather than the smaller. There are no special peculiarities in the disease, but since it is merely part of a general infection, the prognosis is not good. When suppuration has occurred, the joint should be tapped or opened and irrigated.

It may also occur primarily and apart from any other obvious pneumococcal lesion. The symptoms are then those of a subacute arthritis with effusion, which apart from active treatment may lead to subsequent limitation of movement.

Gonorrhœal Disease of Joints is always due to infection with the gonococcus, transmitted by the blood from the primary focus of mischief. It is sometimes associated with pyogenic organisms, and then the prognosis is decidedly worse. In the later stages the pus or serum from the joint is sometimes found to be sterile, the gonococci having died after causing the inflammation. Such an occurrence is always suggestive, as sterile pus is rarely found in an acute abscess due to ordinary pyococci. Whilst usually seen in connection with gonorrhœal urethritis in males, it has been known to follow ophthalmia neonatorum, and has been lighted up by passing a full-sized bougie on a patient with gleet. It generally commences after the third week of the gonorrhœal attack, when the discharge is becoming subacute, but may sometimes appear at a much later period. It may involve one or many joints, the knee, ankle, and wrist being most frequently affected, and perhaps on both sides of the body.

Many distinct types of trouble manifest themselves, and they are not unfrequently combined. In one, the synovial membrane is mainly affected, and the effusion is chiefly intra-articular, so that the condition closely resembles an ordinary attack of acute traumatic synovitis, except that it is more severe, more painful, and more persistent. Occasionally a synovial effusion occurs with but little reaction, and then the gonorrhœal origin is likely to be overlooked. A more frequent form is that in which the peri-articular structures bear the brunt of the mischief; and there is at first but little effusion *in* the joint, but much around it, the parts even becoming œdematous and reddened; the ligaments are infiltrated and softened, so that displacement readily occurs; surrounding muscles atrophy rapidly; the patient suffers from severe pain and fever, so that he becomes thin and worn. In the worst cases the intra-articular effusion increases, and is sero-purulent, yellowish-green in colour, and contains flakes of lymph; sometimes it becomes frankly purulent. All the forms are very chronic and resistant to treatment, and hence ankylosis, with or without disorganization, is very liable to follow.

The **Treatment** of this condition has been considerably modified of late, and the prognosis improved, by a twofold discovery: (*a*) that the virulence of gonococci is attenuated by a temperature which can not only be tolerated by the tissues, but which improves their activities (p. 139); and (*b*) that in diathermy we possess a means of thus in-

creasing the temperature of the part to which it is applied. The results of the diathermic treatment of this condition have been most satisfactory. Of course, additional measures must be taken to arrest the urethral discharge as soon as possible. Sulphanilamide treatment should be given.

If diathermy is not available, the joint should be kept at rest, and moderate pressure and counter-irritation secured by Scott's dressing. Bier's treatment by means of an elastic bandage is also useful, and gonococcal vaccines are sometimes most beneficial. Non-specific antitoxin treatment, *e.g.* the administration of anti-streptococcic or anti-diphtheritic serum, either by mouth or rectum, has also proved of value in some cases, probably acting by increasing the general resistance of the body.

Very severe cases must be treated in the same way as a synovitis of pyococcal origin, *viz.* by incision or tapping and washing out, followed by the introduction of some agent such as glycerine and formalin (2 per cent.); the joint may, if thought desirable, be left open for drainage, but a tube must never be inserted.

Rheumatic Synovitis is met with in the course of acute rheumatism, or as a chronic affection from the commencement. In the former one joint after another is involved; complete resolution usually follows, but there may be some thickening of ligaments and consequent impairment of mobility. If the disease is limited to one joint, absolute disorganization, though without suppuration, may ensue (acute rheumatic arthritis). There can now be little question that this disease is of bacterial origin and due to a diplococcus (Poynton, Paine), or to some form of pyococcal infection of low virulence, as from a chronic pyorrhœa.

The chronic variety is characterized by swelling of the joints, due partly to effusion, partly to thickening of the synovial membrane, and of the capsular and other ligaments. If neglected, it may produce fixity of the joint, due mainly to ligamentous changes, but also resulting from the development of intra-articular adhesions; but there is never any lipping of the cartilages or new formation of bone, as in osteo-arthritis. Not unfrequently other evidences of rheumatism may be present, such as chorea, erythema, etc., whilst rheumatic nodules, *i.e.* new growths of fibrous tissue beneath the skin, perhaps attaining the size of a walnut, but more often much smaller, may also develop.

The **Treatment** of the acute form is in the first place medical rather than surgical, and general rather than local. The affected joints must be kept at rest in good position, and wrapped in warm cotton-wool, or, perhaps better, soda fomentations may be applied. In the presence of a marked effusion, however, there must be no delay in tapping or opening and washing out the joint, which will be found to be occupied by a greenish, semi-puriform effusion.

In the more chronic forms drugs have but little power, and attention must be directed in the main to the general condition of the patient. The diet must be simple, and butcher's meat, sweets, and rich dishes generally must be avoided. Fish, eggs, and poultry should constitute the chief elements of the protein food. Abundance of

plain water must be drunk, either hot or cold as best suits the patient, but *not at meals*; the fluid should always in these cases be imbibed about an hour before meals. In the early morning before breakfast, it is often wise to add a small dose of Epsom or Glauber's salt to the water, and thus procure a slight purgative effect, thereby cleansing the intestine. Thus it is possible even at home to secure many of the advantages derived from a visit to a suitable spa, which in persistent cases is very desirable. In addition, acid fruits and vegetables should be avoided, such as rhubarb, tomatoes, and the 'berries' generally. Locally, inunction of an ointment containing some suitable form of iodine, possibly combined with oil of wintergreen (methyl salicylate) is often helpful, but possibly the result is as much due to the massage as to the ointment. Hot-air baths are also good, as also ionic medication with sodium salicylate (p. 303), or diathermy (p. 297). Of course, care must be taken to prevent deformity if practicable, or to correct it, but this is often not an easy matter.

The practitioner must not forget to overhaul the patient thoroughly to ascertain whether or not there is any source of pyococcal infection in the body. Particular attention must be devoted to the teeth and gums; removal of septic roots and decayed teeth has often a marvellous effect in curing so-called rheumatism. Diseased tonsils, chronic suppuration of the nasal passages, chronic urethritis, or leucorrhœa, may also be causative factors, and must be dealt with in an appropriate fashion.

Gouty Arthritis is characterized by certain well-marked features. It often attacks the metatarso-phalangeal articulation of the great toe (podagra), or the metacarpo-phalangeal joint of the thumb (cheiragra). Its onset is usually sudden, and it frequently commences in the middle of the night. The tissues around the joint become swollen, red, shiny, and œdematous, whilst the superficial veins are prominent. The attack is exceedingly painful, and the skin exquisitely tender. These symptoms pass off in the course of a few days, leaving the articulation swollen and sensitive.

Even a single attack results in a slight deposit of bi-urate of soda in acicular crystals in the matrix of the articular cartilage close to the surface; but when the joint has been several times inflamed, the whole thickness of the cartilage may be invaded by this chalky deposit, whilst the ligaments and ends of the bones are also infiltrated. In the smaller joints it may increase to such an extent as to form well-marked swellings, or 'tophi,' similar in character to those so commonly seen in the external ear; the skin sometimes gives way over them, and a chalky discharge results. In some cases the cartilages are eroded, and eburnation of the exposed bone may follow, as in osteo-arthritis. The **treatment** of acute gout consists in fomenting the parts or applying glycerine of belladonna, whilst colchicum, citrate of lithia, and alkaline purgatives are administered. In the more chronic forms iodides may be given, and the diet and drink are carefully regulated. Probably some form of hydro-therapeutic treatment will be required, and if the patient cannot go to a suitable spa much may be done at home by getting him to drink a large glassful of hot water an hour before each meal.

Chronic Synovitis.

This affection follows an acute attack, or may be lighted up by some injury or condition insufficient to determine a more violent form of inflammation. The synovial membrane becomes thick and infiltrated, whilst the effusion is sometimes relatively less than in the acute form, sometimes excessive.

Three varieties have been described: (*a*) **Chronic Serous Synovitis** (Fig. 425) is a condition in which effusion is the most prominent factor. It results from many causes, which throw strain upon the joint, or is sometimes inexplicable. It is not unfrequently associated with some condition such as a loose cartilage, osteo-arthritis, etc., and in its most aggravated form constitutes a condition of *hydrarthrosis* or *hydrops* (p. 740). It is not unfrequently seen affecting the knees after rising from a prolonged stay in bed. The fluid is often clear and limpid and the changes in the structure of the membrane are but slight. The pain is usually not severe, being replaced by a sense of uselessness and weakness. It is interesting to note that, in cases where the effusion is well marked, the bursæ communicating with the joint frequently become distended; they are prevented from participating in the acute forms of inflammation by the fact that the apertures of communication with the interior of the joint are narrow and slit-like, and thus readily become occluded by the swelling of the membrane.

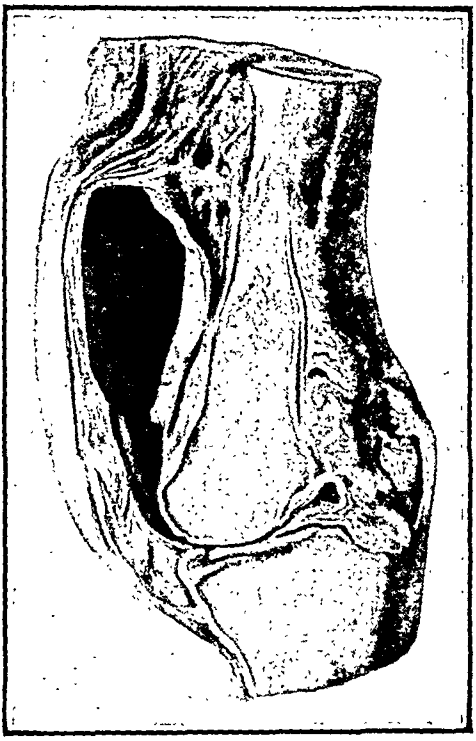


FIG. 425.—CHRONIC SEROUS SYNOVITIS OF KNEE, WITH DISTENSION OF THE SUBCRURAL POUCH. (FROM COLLEGE OF SURGEONS MUSEUM.)

(*b*) **Chronic Synovitis with thickening of the Synovial Membrane** is always a suspicious condition, as it may be a precursor of tuberculous disease, if it lasts, or an outcome of a syphilitic infection. There is but little effusion, and the membrane may be even palpable. Crepitus is sometimes met with in this condition, possibly from a roughening of the articular surfaces on which lymph has been deposited, or between which fibrous adhesions have formed.

(*c*) **Chronic Papillary Synovitis.**—Occasionally the synovial fringes and the villi of the synovial membrane become hypertrophied, giving rise to a condition somewhat similar to that described under osteo-arthritis (p. 753). The overgrown villi usually spring from the reflections of the synovial membrane close to the bone, and may be loaded

with fat, constituting a condition known as 'Lipoma arborescens.' In the knee-joint the fringes may be felt rolling under the fingers, and painful symptoms may be caused by the loose ends being caught and nipped between the bones.

Treatment varies somewhat in the different types, but in all the joint must be kept at rest in a suitable position, and counter-irritation and pressure applied; Scott's dressing and blisters are especially useful in this affection. At a somewhat later stage Bier's hyperæmia may be helpful, or elastic pressure by a Martin's bandage, together with friction with stimulating liniments, or hot-air baths. When effusion is marked and resists these methods of treatment, removal of the fluid by aspiration and subsequent compression may do good; but if the effusion reappears, the best procedure consists in opening the joint, and washing it out with sterile saline solution.

In the chronic fibroid form iodide of potassium may be useful in addition to the above-mentioned methods, but as a rule one has to rely on prolonged massage, radiant-heat baths, ionic medication, or spa treatment.

Should enlarged villi be present and give rise to trouble, the joint should be opened, and if they are limited in their distribution they may be clipped away, or the synovial membrane from which they grow dissected out.

Hydrarthrosis (Hydrops Articuli) is the term applied to any condition of a chronic nature in which the joint is much distended with fluid. It may arise from at least five different affections: (*a*) Chronic serous synovitis; (*b*) in osteo-arthritis, a very common cause; (*c*) in Charcot's disease; (*d*) in secondary syphilitic synovitis; and (*e*) occasionally in tuberculous disease. It must be remembered that it is but a symptom, and not a disease *sui generis*, and treatment necessarily varies with the cause.

Baker's Cysts.—This condition, first described by the late Mr. Morrant Baker, consists in a hernial protrusion of the synovial membrane of a joint through an aperture in its fibrous capsule. It is usually due to some chronic affection of the articulation, especially osteo-arthritis or tuberculous disease, whereby the intra-articular pressure is increased, and not uncommonly several such sacs are connected with the same joint. They vary much in size, contain synovial fluid, and, though at first communicating with the joint cavity, have a tendency to travel away from it, burrowing along muscular and fascial planes, and coming, perhaps, to the surface at a distance from their origin, the aperture of communication with the joint having in some instances been shut off. If causing no troublesome symptoms, there is no necessity to interfere; but if they become inconvenient or painful, it is best to dissect them out, closing where possible by ligature or suture the narrow neck which leads into the joint. Of course, the strictest asepsis must be maintained in all such proceedings, and the causative affection must not be forgotten.

Tuberculous Disease of Joints.

Tuberculous Arthritis may commence either in the synovial membrane or in the articular end of the adjacent bone (tuberculous epiphysitis, p. 655); or it may spread to the synovial membrane from the periosteum, as a result of a tuberculous periostitis, or from a neighbouring bursa. In children the disease commences most frequently in the epiphyses, whilst in adults it may start either in membrane or bone with about equal frequency, but considerable variation occurs according to the particular joint affected.

The **Causes** may be summed up as follows: The individual is predisposed to the development of tuberculous disease, often as the result of an inherited tendency; the general health of the patient may also be at fault. Some slight injury, of which but little notice is taken, may lead to the actual deposit of the *B. tuberculosis*, which has been probably lying latent in the bronchial or mesenteric glands, or is present in an active state in the lungs. Severe articular lesions, such as dislocations, are less likely to induce tuberculous disease, partly because their gravity demands efficient treatment, partly because the activity of the reparative process is capable of dealing with the organisms, even if they are brought to the spot.

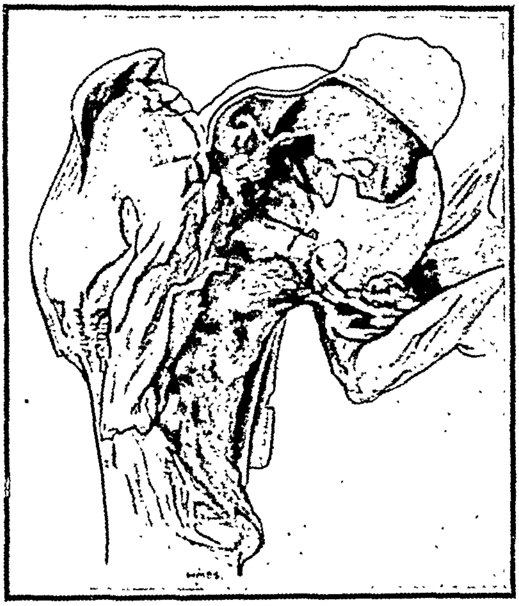


FIG. 426.—TUBERCULOUS DISEASE OF HEAD AND NECK OF THE FEMUR.

The disease evidently started on the under side of the neck, which has been eroded, and spread into the head; the articular cartilage is loose, and necrotic fragments of it have been stripped up off the bone.

Pathological History. — The *synovial membrane* becomes thickened, pulpy, and œdematous, and in the early stages is found to be studded with small gelatinous nodules about the size of a pin's head, situated immediately beneath the serous lining; later on, these may amalgamate into caseous masses, which burst and discharge into the joint, leaving ulcerated surfaces. Occasionally these masses are of considerable size; more often they are only small. Finally, the synovial membrane is changed into a so-called pyogenic membrane, consisting of granulation tissue similar to that lining the cavity of a chronic abscess, and more or less closely attached to the surrounding structures, which are transformed into œdematous fibro-cicatricial tissue, whilst the superficial parts undergo fatty or necrotic changes. Fringes of the synovial membrane, swollen and succulent, spread over the

margins of the *articular cartilage*, and as they increase in size become adherent to it, just as, according to Billroth's classical description, ivy creeps along a wall. On lifting the edges of these fringes, the underlying cartilage is found hollowed out and eroded. As soon as the whole thickness is destroyed at any one spot, the cancellous tissue at the *end of the bone* becomes invaded by the tuberculous disease, giving rise to caries which is more or less extensive (Fig. 427), and may be associated with necrosis. The granulations spread along under the cartilage, cutting it off from its nutritive supply, and thus large flakes of necrosed cartilage may be shelled off (Fig. 426). New formation of subperiosteal bone is unusual in tuberculous disease, but if pyococcal infection supervene, it may occur. Occasionally, the periosteum itself is involved in the tuberculous process, and the disease may then extend some distance from the joint.

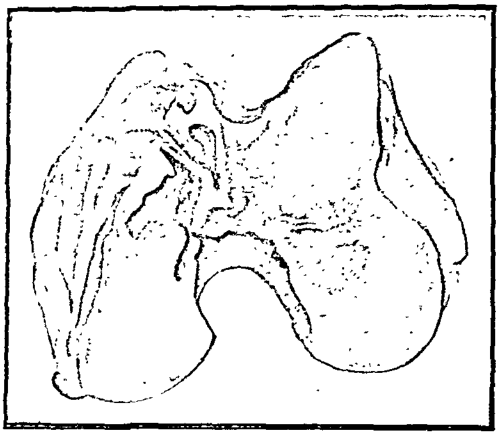


FIG. 427.—TUBERCULOUS DISEASE OF THE LOWER END OF THE FEMUR.

The cartilage is partly destroyed, and the exposed bone is carious and eroded.

The joint itself usually contains but little fluid, being fully occupied by the swollen synovial membrane; but occasionally in the early stages there is much effusion, constituting a condition known as *tuberculous hydrops*, and in it there may be a considerable amount of fibrin, which is moulded by the movements of the joint into the so-called melon-seed bodies. The chief cytological element in the effusion is the lymphocyte.

The perisynovial tissues are frequently affected in these cases, especially where there is much loose fatty tissue, as around the knee. The parts are infiltrated and gelatinous, and muscles and tendons are incorporated in the swelling and modified similarly in texture. This change constitutes a large element in what is known as the *white swelling* of a joint.

When the disease originates in the bone in adults, the tissue directly contiguous to the articular cartilage is often that primarily attacked; but in children it more frequently starts in connection with the epiphyseal cartilage. The joint is usually infected by extension of the disease through the articular cartilage; but when the synovial membrane extends along the bone beyond the cartilage, as in the hip-joint, it may become involved without any cartilaginous lesion. In the early stages a simple synovial effusion may occur, and should the osseous trouble quiet down and be cured, this may be absorbed, and merely a few adhesions be left. Most commonly the infection is due to the gradual erosion of the cartilage towards its periphery, and the onset of the articular symptoms is then of a chronic type. Sometimes, however, a tuberculous abscess of the bone or surrounding

parts bursts into a joint; acute symptoms supervene, but gradually quiet down, and the usual chronic phenomena subsequently develop.

Clinical History.—The disease usually commences in a most insidious manner. It may be dated back to some injury, but as often as not no such occurrence has been noted. Slight impairment of movement, together with some pain, especially when the limb is jarred or twisted, is perhaps the first sign, causing the patient to limp if one of the lower extremities is involved. This limitation of movement is usually manifested in *all* directions, and this will often assist in diagnosing it from the fixity due to the presence of adhesions in a simple chronic synovitis. The amount of rigidity varies much; in a purely synovial lesion the movements may at first be painless and but little impaired, although the whole region of the joint may be puffy and swollen; when, however, the bone is affected, either primarily or secondarily, the limitation of movement is considerably increased. The position of the limb is that which will give the greatest amount of comfort, and varies in different joints (*q.v.*) and at different stages of the disease. On inspection a superficial joint, like the knee, looks white, smooth, and rounded (constituting the 'white swelling,' or tumor albus of the older textbooks), the swelling being more apparent on account of the wasting of adjacent muscles. On palpation, the part is found to be slightly hotter than that on the opposite side of the body, whilst fluctuation is not readily detected, there being but little fluid in the joint, though the affected tissues are elastic and puffy. In a few cases, where the synovial membrane is widely involved, the affection commences with considerable serous exudation, giving rise to the condition known as *tuberculous hydrops*; after persisting for a while, the usual manifestations of the disease show themselves. If fibrinous melon-seeds are present, a soft crepitus may be felt on moving the joint.

From time to time exacerbations of pain and increase of swelling occur, which subside after resting for a few days, but leave the joint more and more crippled. Starting pains at night develop when the cartilages are becoming eroded, together with slight fever and malaise. Sooner or later an abscess forms, with increased local and general disturbance; when it bursts or is opened, temporary relief is experienced, but fresh abscesses are liable to form. If pyogenic infection supervenes, the patient develops a hectic temperature; amyloid degeneration of the viscera may follow; the limb becomes more and more deformed; and finally the patient, exhausted partly by the discharge, partly by the pain, and partly by want of sleep, becomes emaciated, and may even die unless prompt measures are taken for his relief.

Results.—Where efficient treatment is instituted before there is any X-ray evidence of bony involvement, a good result with very little impairment of mobility is the usual outcome. But where the articular cartilage is eroded, much limitation of movement with the formation of adhesions must be expected. Sometimes tuberculous foci are encapsuled in this fibrous tissue, and may cause further pain and trouble from time to time, so that many authorities consider that these cases are often better treated by endeavouring to establish bony ankylosis by operative interference. If the condition progresses

to suppuration and pyococci are admitted, the disease is aggravated, and unless effective drainage is provided, the bone ends become carious, sinuses form, discharging a varying quantity of pus, and the patient may be exhausted by toxæmia or amyloid disease. Where such dangers are escaped and yet the disease progresses uncured, the limb becomes more and more crippled, and the patient lives more or less an invalid life, with sinuses which dry up or discharge at times, and are a constant source of danger and annoyance. Finally, acute miliary tuberculosis may supervene as a complication at any time, or a tuberculous affection of the lungs, brain, kidney, or other viscera, and may prove fatal.

The **Diagnosis** is by no means easy in all cases, although sometimes it is tolerably obvious. One can never insist too often on the importance of comparing the diseased joint with the healthy whenever possible, observing the differences in contour, colour, temperature, and mobility. The history of the case must be carefully noted, the amount and character of the effusion, and whether or not lymphocytes predominate in a cytological examination; the amount of movement must be ascertained, and whether the limitations are general or particular. Radiography may help, and especially in distinguishing purely osseous conditions, *e.g.* sarcoma of the end of the bone. Aspiration of the fluid from a joint and injection of this into guinea-pigs, or even the removal of a portion of the synovial membrane by an open operation followed by microscopical examination of this tissue, may be required to aid the diagnosis.

The **Prognosis** is mainly dependent on the stage when the condition is recognized, and on the possibility of securing suitable treatment. School clinics have done much to ensure the early recognition of this condition in children of school age, and the provision of sanatoria, etc., by public authorities is good, as far as it goes. But there is abundant call for more beds for these cases, and also for some provision to ensure the medical oversight of children under school age. The results of modern treatment are usually good, and, indeed, the complaints of hospital surgeons that they can obtain no material of this type to teach from is most satisfactory. Of course, slum children and those of poor physique generally or with a grave tuberculous inheritance are liable not to benefit as do others. The extremes of life also are unfavourable; babies resist tuberculous invasion badly, whilst patients over fifty years of age have sometimes comparatively little recuperative power.

The **Treatment** of tuberculous joints is conducted along lines similar to those employed for other tuberculous foci.

1. *General* treatment of the sanatorium type (p. 175), or its equivalent, must be instituted as early as possible after a diagnosis is reached, and should be maintained at least until the active stage of the disease has terminated, but for preference until the condition is presumably cured.

2. During this period *local* treatment must be maintained with the twofold end in view, not only of curing the disease, but also of leaving the limb subsequently in as good a functional condition as regards

position and movement as possible. In the early stages absolute rest is essential, and must be secured by splints, plaster of Paris, etc.; if there is much pain, and particularly if of the starting type, extension must be applied—just enough to keep the tender ends of the bones from pressing one against the other. Extension is also applied in these cases, especially as regards the hip-joint, where owing to a trivial or even no bony involvement an endeavour is going to be made to establish a fully mobile joint and not an ankylosed one. Undue weight may cause stretching of the ligaments and subsequent laxity of the joint. Rest must include not only freedom from mobility, but also the absence of pressure; and therefore for all joints of the lower extremity the patient must be put to bed. It is obvious that bed is also indicated for affections of the upper limb in the more active stages. As the condition improves, the patient is allowed to get up, but the same restrictions as regards rest must be maintained to the end of the chapter.

Inasmuch as there is always a likelihood of the development of ankylosis, the position in which the limb is placed is of great importance (see on p. 721). If the position of the limb is already bad when first seen, endeavours to correct it must be instituted at once, and for this purpose weight extension must be relied on. At first it is made in the direction of the displaced limb, and with only just sufficient energy to keep the articular surfaces at rest; gradually the tonic muscular contraction will disappear, and the malposition with it. At other times a little assistance is required in the direction of pressure applied locally to help a displaced bone into position. Tenotomy may occasionally be needed, but any form of apparatus which depends on a screw mechanism is undesirable, as it increases intra-articular tension. The sudden application of force under an anæsthetic is totally inadmissible, as thereby tuberculous material may be disseminated through the system. Scott's dressing is sometimes useful locally for the more superficial joints, and Bier's hyperæmia may occasionally be employed.

3. *Abscesses* should be dealt with sufficiently early and in such a manner as to obviate the need for drainage. To this end they ought never to be left until the skin and subcutaneous tissues are involved; but as soon as a collection can be detected, it should be aspirated, or, if need be, irrigated.

Of course, when the skin is thin and reddened, and the pus subcutaneous, the abscess must be incised and drained in the usual manner, any thin and undermined skin being snipped away.

4. Effective sanatorium treatment and prolonged immobilization in a correct attitude have greatly destroyed the *operative treatment* of tuberculous joints, and therefore the following section may appear a little out of date; its retention is justified by the fact that the 'ideal' is not always attainable, and surgeons have sometimes to practise the 'best possible.'

A simple *arthrotomy* is sometimes useful. The joint is incised and washed out thoroughly. Disintegrated and loosened cartilages are removed; tuberculous débris is cleared away; the joint cavity is dried

out with alcohol and ether, and the exposed surfaces are then 'bipped.' The cavity is closed, and the limb placed in a suitable position and immobilized. Ankylosis will probably result.

Arthrectomy, or erasion, consists in dissecting away all the diseased tissues that can be reached through a free incision. The synovial membrane is cut away; diseased foci of bone are gouged out, and the resulting cavities disinfected by alcohol and 'bipped.' Ankylosis is the usual result. It is obvious that this proceeding is not equally applicable to all joints. Thus, in the hip the opening is usually made from the front, and unless there is great laxity of the capsule and some increase in size of the acetabulum, the back and upper part of the joint cannot be reached. The knee, ankle, and elbow are the most favourable situations for this operation. The chief advantages are that it interferes neither with the immediate length nor with the subsequent growth, whilst there are no extensive sections of healthy bone exposed to infection.

Excision is a more radical measure, but has the disadvantage of removing healthy as well as diseased tissues; whilst the fact that it encroaches on the epiphyseal structures renders it undesirable in children. The chief conditions for which it is now employed in tuberculous disease are: (*a*) For complete disorganization of the joint; (*b*) to prevent ankylosis in certain joints, such as the elbow and temporo-maxillary; (*c*) to determine a rapid and radical cure with synostosis in such a joint as the knee, as soon as it is evident that the natural result of the disease must be an ankylosed limb. Surgical art often produces a more efficient cure than Nature under these circumstances, since all foci can be removed. A natural cure often leaves encapsuled many tuberculous foci, and these may subsequently cause pain and lead to recurrent attacks of inflammation. (*d*) Deformity with or without ankylosis may justify excision.

Amputation is required in cases which, in spite of every care, are steadily going from bad to worse, and where the patient's health and strength are being sapped by the disease. It is needed not unfrequently in old people, and is indicated in patients where excision has been undertaken and failed, either from the limb becoming subsequently flail-like or useless, or from recurrence owing to incomplete eradication, or from the advent of pyogenic infection. Lastly, if the disease is present in two joints at one time, or in a joint and some other organ, neither of which is improving, total removal of one focus of mischief will often induce a rapidly favourable change in the other.

The choice of operation in any particular case is dependent on a variety of factors which must be taken into consideration: (i.) The *age* of the patient. Typical excisions encroach on the growing ends of bones and render them undesirable in children, for even if growth is not stopped thereby, it may be rendered irregular and cause subsequent deformity. As regards advanced age, the shoulder and knee may be excised satisfactorily later than the elbow, wrist, and ankle. Probably forty to forty-five years would be looked on as the age limit for the latter, but excellent results have been obtained from excising the knee and shoulder at a much later period of life.